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TECHNICAL SUPPORT DOCUMENT FOR THE VOLUNTARY ADVANCED TECHNOLOGY INCENTIVES PROGRAM

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LIST OF ACRONYMS

ADMT	Air-dried metric ton
AOX	Adsorbable organic halide
BAT	Best available technology economically achievable
BFR™	Bleach Filtrate Recycle™
BMP	Best management practices
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CRP	Chloride Removal Process
ECF	Elemental chlorine free
LTA	Long term average
ML	Minimum level
MRP	Metals Removal Process
NCASI	National Council of the Pulp and Paper Industry for Air and Stream Improvement
TCF	Totally chlorine free

1.0 GOALS OF THE VOLUNTARY ADVANCED TECHNOLOGY INCENTIVES PROGRAM

EPA has promulgated new BAT limitations that will achieve significant pollutant reductions using technologies within the economic capability of the bleached papergrade kraft and soda subcategory as a whole. EPA wants to encourage additional pollutant reductions by promoting the widespread use and perfection of new technologies such as extended delignification and the development of even more advanced technologies, such as those aimed at reducing pulping and bleaching discharge flow. EPA also wants to encourage the widespread use and perfection of totally chlorine free bleaching processes. These technologies and processes have the ability to surpass the environmental protection that would be provided by compliance with the baseline BAT limitations. Indeed, EPA's vision of long-term environmental goals for the pulp and paper industry includes continuing research and progress toward such environmental improvement. The Agency believes that individual mills can be encouraged to make substantial environmental progress beyond the base level compelled by law. For this reason, EPA is establishing a Voluntary Advanced Technology Incentives Program to encourage mills to move beyond today's baseline BAT technologies toward the "mill of the future," which EPA believes will have a minimum impact on the environment.

As a result of the Voluntary Advanced Technology Incentives Program, EPA hopes to achieve greater pollutant reductions than it could achieve through baseline BAT limitations and NSPS. Indeed, the development of increasingly more advanced process technologies that minimize the discharge of wastewater and wastewater pollutants is a critical step toward the Clean Water Act's ultimate goal of eliminating the discharge of pollutants into the Nation's waters. Therefore, the Voluntary Advanced Technology Incentives Program promotes EPA's statutory goal and establishes limitations that act as a beacon to show what is possible.

EPA is interested in encouraging development of advanced technologies for broader commercial applications. As these technologies are proven and their efficiencies publicized, EPA hopes that they will become standard industry practice. Thus, EPA believes it is in the public interest to encourage mills today to develop environmentally beneficial technology and to reward mills that are innovative and forward-looking in their use of new and more environmentally effective technology despite its greater cost.

In order to stimulate further long term environmental improvements, EPA has assembled a number of incentives relating to permitting and enforcement matters and public recognition. If mills accept enforceable NPDES permit limitations at one of the Tier levels, they will qualify for the incentives program at that level. In some instances the incentives will actually serve as rewards for effluent reductions already achieved, while greater incentives will be available for greater reductions in pollutant discharge required by the more advanced tiers.

EPA is providing incentives in the form of additional compliance time and greater predictability in its rulemaking for this industry. EPA is allowing additional time for compliance, 6 years for Tier I, 11 years for Tier II, and 16 years for Tier III. A mill would need to commit to the program and submit a plan for achieving limits within the first year. The balance of the time would be needed to arrange financing and develop, install, test, and implement at full scale the Advanced Technologies chosen by each mill to achieve the ultimate tier limits. EPA is promulgating Voluntary Advanced Technology BAT limitations at the same time as baseline BAT limitations to allow interested mills to consider all technology options at the outset before they make their investment decisions and to design and install precisely the technologies and processes they will need to meet their long-term Advanced Technology objectives. This will provide mills with an opportunity to push their environmental performance beyond the minimum prescribed by the baseline BAT and also provide predictability regarding the progress expected of Advanced Technology mills over time. EPA hopes that this predictability, along with additional time for compliance, will encourage greater participation in the program, lead to superior effluent quality, and avoid the uncertainties inherent in a succession of later rulemakings.

The MACT I rule also provides mills with additional compliance time for high volume low concentration (HVLC) sources on a fiber line, including brownstock washers and oxygen delignification vents. This additional time is intended to facilitate implementation of pollution prevention technologies such as extended delignification.

EPA also will provide as an incentive public recognition as soon as a mill accepts Voluntary Advanced Technology BAT limitations in its NPDES permit. Public recognition will continue as long as interim milestones and the ultimate tier limits are achieved. EPA also is providing as an incentive reduced effluent monitoring applicable to dioxin, furan, chloroform and the 12 chlorinated phenolic pollutants as soon as participating mills achieve those limitations. The remaining incentives, including greater permit certainty, reduced inspections, and reduced penalties, are available after the mill achieves the ultimate Advanced Technology performance levels.

1.1 Minimum-Impact Mill

Leaders in the pulp and paper industry have adopted the concept of minimum-impact manufacturing or the minimum-impact mill as the best strategy for creating sustainable value for all stakeholders associated with the pulp and paper industry: affected communities, employees, customers, and shareholders [123]. The minimum-impact mill is succinctly described by Gerald Crosset of Champion as one where "the total production process is integrated into a closed system. Use of fiber and other raw materials is maximized. Water usage is minimized. Air, water and solid emissions are negligible and there is very little waste. There are aggressive efforts to continuously improve the environment and cost performance. The mills coexist in harmony with their neighboring communities." An additional important component of the minimum-impact mill is that overall energy consumption is minimized. The desirability of pursuing the minimum-impact mill concept is shared by major environmental groups and purchasers of paper products [4]. The Voluntary Advanced Technology Incentives Program is structured to encourage the pulp and paper industry to pursue this vision of the minimum-impact mill.

1.2 Background

Worldwide development and implementation of the technologies required by minimum-impact mills is occurring rapidly. These technologies minimize discharges from mills and conserve resources through internal recycle of process effluents. A number of bleached kraft mills in the U.S. and Scandinavia are pursuing these technologies, including mills using both elemental chlorine free (ECF) bleaching and totally chlorine free bleaching (TCF) bleaching [5]. The specific mills leading the way and the technologies being used are discussed in Section 3.0 of this report. EPA expects that this rapid technological development will continue over the next 15 years, and that the Voluntary Advanced Technology Incentives Program will encourage progress in this arena.

2.0 SUMMARY OF THE INCENTIVES PROGRAM

EPA is establishing three tiers of Advanced Technology performance requirements, each with unique limitations and standards based on the underlying model technology particular to that tier. To promote ambitious use of Advanced Technologies, EPA is offering greater incentives to mills that achieve the more advanced tiers, thereby realizing greater reductions in pollutant discharges. EPA has established the incentives tiers so that they can be achieved by mills using either elemental chlorine free (ECF) bleaching technology or totally chlorine free (TCF) bleaching technology.

The incentives program is available to existing and new direct discharge mills. EPA has decided not to make it available to indirect dischargers at this time because it would be much more difficult to administer than the baseline PSES program and therefore would impose a substantial burden on local governments.

2.1 Performance Requirements

EPA has established performance requirements for each tier, in the form of Advanced Technology BAT limitations and new source performance standards, that reflect degrees of environmental protection that can be achieved with increasing application of advanced technology. These performance requirements, which are codified at 40 CFR 430.24(b) and 430.25(c), are summarized in Table 2-1.

While not a performance criterion that would be an NPDES permit limitation, EPA assumes that mills choosing to participate at Tier I will implement BMPs equal to or more stringent than those necessary to comply with the minimum BMP requirements in 40 CFR 430.03. Similarly, EPA also assumes that mills choosing to participate at Tiers II and III will implement even more stringent BMPs to further reduce and move toward the elimination of leaks and spills, while also capturing and recycling (rather than discharging) liquors during fiber line disruptions through detailed planning of maintenance outages and contingency planning for unexpected disruptions.

Table 2-1

Incentives Tiers Performance Requirements[1]

Tier	Criteria	Performance Requirement
I	AOX long-term average	` 0.26 kg/kkg
	Kappa to Bleaching: Softwood Hardwood	 ` 20 ` 13
	All filtrates must be recycled prior to the point where kappa is measured.	
II	AOX long-term average	` 0.10 kg/kkg
	Pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow	` 10 m^3/kkg
	Pulping area effluents containing black liquor solids generated prior to bleaching must be recycled to chemical recovery.	
III	AOX long-term average	` 0.05 kg/kkg
	Pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow	` 5 m^3/kkg
	Pulping area effluents containing black liquor solids generated prior to bleaching must be recycled to chemical recovery.	

[1]All mills enrolled in the Voluntary Advanced Technology Incentives Program must also achieve limitations for dioxin, furan, chloroform, and 12 chlorinated phenolics equivalent to the baseline BAT levels for those pollutants.

2.1.1 Tier I Voluntary Advanced Technology BAT Limitations

For Tier I, the ultimate performance requirement for AOX is a long-term average (LTA) discharge of 0.26 kg/kkg or below, measured at the end of the pipe. This requirement is expressed as kg AOX per kkg air dried pulp; kkg is equivalent to air dried metric ton, or ADMT. See 40 CFR 430.24(b)(4). Under Tier I, fiber lines at participating mills must also achieve reduced lignin content in pulps prior to bleaching as measured by a kappa number of 20 for softwoods and 13 for hardwoods and reported as an annual average. Id. Finally, Tier I Advanced Technology fiber lines must recycle to recovery systems all filtrates up to the point at which the unbleached pulp kappa numbers are measured (e.g., brown stock into bleaching). Id. Tier I also includes limitations for dioxin, furan, chloroform and 12 chlorinated phenolic pollutants. See 40 CFR 430.24(b)(3). Limitations on these parameters are established at the baseline BAT levels because application of Advanced Technologies does not appear to justify more stringent limitations.

2.1.2 Tier II Voluntary Advanced Technology BAT Limitations and NSPS

For Tier II, the ultimate performance requirement for AOX is an LTA discharge of 0.10 kg/kkg or below, measured at the end of the pipe. In addition, Tier II Advanced Technology fiber lines must recycle to chemical recovery systems all pulping-area effluents generated prior to bleaching that contain black liquor solids (i.e., no planned or routine releases of black liquor solids to the wastewater treatment system from any pulping area sources or systems). Tier II Advanced Technology fiber lines must also achieve total pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow of 10 m^3/kkg or less reported as an annual average. Tier II mills must also meet limitations for dioxin, furan, chloroform, and the 12 chlorinated phenolic pollutants. See 40 CFR 430.24(b)(3) and (4) and 40 CFR 430.25(c).

2.1.3 Tier III Voluntary Advanced Technology BAT Limitations and NSPS

For Tier III, the ultimate performance requirement for AOX is an LTA discharge of 0.05 kg/kkg or less, measured at the end of the pipe. In addition, Tier III Advanced Technology fiber lines must recycle to chemical recovery systems all pulping-area effluents generated prior to bleaching that contain black liquor solids (i.e., no planned or routine releases of black liquor solids to the wastewater treatment system from any pulping area sources or systems). Finally, Tier III Advanced Technology fiber lines must also achieve total pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow of 5 m^3/kkg or less reported as an annual average. Tier III mills must also meet limitations for dioxin, furan, chloroform, and the 12 chlorinated phenolic pollutants. See 40 CFR 430.24(b)(3) and (4) and 40 CFR 430.25(c).

2.1.4 Voluntary Advanced Technology BAT Limitations and NSPS for Mills Employing TCF Processes

Existing dischargers that choose to employ TCF processes are subject to the ultimate performance requirements discussed above. However, data gathered from TCF mills indicate that TCF mills will be able to achieve the AOX performance requirements at any tier level because end-of-pipe AOX concentrations are below detection limits when mills operate in a TCF bleaching mode on a consistent basis. Consequently, the AOX limitations for TCF fiber lines are expressed as "<ML." See 40 CFR 430.24(b)(3) and (4) and 430.25(c)(2). In addition, unlike fiber lines using ECF processes to achieve Tier II or III BAT limits, TCF fiber lines would not receive limitations on the discharge of dioxin, furan, chloroform, or the 12 chlorinated phenolics if they certify as part of their permit application that the bleaching process at those fiber lines does not use chlorine-based compounds.

2.2 Regulated Parameters

2.2.1 AOX

EPA chose to use AOX as a performance standard for each of the three Voluntary Advanced Technology BAT tiers because AOX is a measure of progress in reducing the total chlorinated organic matter in wastewaters resulting from the bleaching of pulps. There is a correlation between the presence of AOX and the amount of chlorinated chemical used in relation to the residual lignin in the pulp (expressed as the kappa factor). There is a further correlation between the kappa factor and the formation of dioxin and furan [6]. Therefore, EPA concluded that reducing AOX loads will have the effect of reducing the mass of dioxin, furan, and other chlorinated organic pollutants discharged. In addition, the use of AOX rather than other measures of organic matter (e.g., BOD) will further encourage a pollution prevention approach instead of end-of-pipe treatment technologies.

2.2.2 Kappa Number

In addition to the AOX criterion, EPA's BAT limitations requirements for Tier I include kappa numbers measured prior to bleaching. See 40 CFR 430.24(b)(4)(i). The kappa number is a measure of lignin content in unbleached pulp, and is routinely determined by mills on an ongoing basis.

EPA is requiring Tier I mills to achieve specified kappa numbers that reflect the performance capabilities of well-operated extended delignification systems. Extended delignification removes lignin from pulp prior to bleaching. The lower lignin content results in lower bleaching chemical demands than a traditional bleaching sequence, because the unbleached kappa number is lower and the subsequent bleaching chemical requirements drop relative to this [7]. In addition, bleaching to a particular brightness can often be accomplished using fewer bleaching stages than a traditional bleach line if extended delignification is used. Decreased bleaching chemical use reduces pollutant levels in the mill's bleach plant effluent. Although the operation of extended delignification in itself does not decrease the effluent flow from the bleach plant, it can lessen water use if older, less efficient bleaching towers and associated interstage washers are bypassed. The lignin released by extended delignification is removed by subsequent washing stages and sent to the recovery boiler, marginally increasing the load on the boiler, but concurrently increasing the amount of recovered pulping chemicals and energy. Based on data for oxygen delignification systems, recycling the filtrates from these washers, rather than sending them to wastewater treatment, reduces the bleach plant effluent load of biochemical oxygen demand (BOD) by 30 to 50 percent, chemical oxygen demand (COD) by 40 percent, color by approximately 60 percent, and chlorinated organics by approximately 35 to 50 percent (7)[8]. In addition, by meeting the kappa number limitations in concert with efficient brown stock washing, Tier I mills will achieve much greater reductions in precursors for chlorinated organic pollutants found in lignin than those achieved by mills with conventional pulping processes.

2.2.3 Flow

Mills in Tier I of the Voluntary Advanced Technology Incentives Program are required to recycle all filtrates to chemical recovery prior to the point where kappa is measured, eliminating an important source of weak black liquor discharge that would otherwise go to the mill's wastewater treatment plant. These filtrates include, but are not limited to, brown stock washer filtrates, screen room decker filtrates, and post oxygen wash filtrates. At Tier II and Tier III, mills also are required to recycle all pulping area filtrates to chemical recovery. In addition to these filtrates, Tier II and Tier III mills must eliminate planned or routine releases of black liquor solids to the wastewater treatment system from any other pulping area systems or sources.

Recycling of pulping area filtrates and other sources of black liquor solids to the chemical recovery cycle prevents the discharge of weak black liquor, which includes inorganic pulping chemicals and dissolved wood substances. The dissolved wood substances include polynuclear aromatic hydrocarbons, degraded carbohydrates, low-molecular weight organic acids, and wood extractives (resins and fatty acids). The toxicity of the materials contained in black liquor is well documented; see the Technical Support Document for Best Management Practices for Spent Pulping Liquor Management, Spill Prevention, and Control [9].

The Tier II and Tier III BAT limitations and NSPS also include restrictions on the discharge of total pulping area and evaporator condensate and bleach plant wastewater, thereby moving mills toward minimum effluent operations. Reductions in flow will have the effect of dramatically reducing mass loadings--and discharges--of nonchlorinated organics such as lignin and a variety of chlorinated organics in addition to dioxin, furan and the chlorinated phenolic pollutants specifically regulated. Because these pollutants are far too numerous to measure individually (and most have not been specifically isolated and identified), EPA determined that it was impracticable to set mass-based limits for all of them. EPA judged that establishing flow levels for Tiers II and III would be the best way to control the discharge of these pollutants.

2.2.4 Other BAT Pollutants

Except for TCF-based processes, BAT limitations and NSPS for each Advanced Technology tier includes limitations on the discharge of dioxin, furan, chloroform, and 12 chlorinated phenolic pollutants monitored at the bleach plant.

3.0 ADVANCED TECHNOLOGY TIERS

EPA is codifying three tiers of Voluntary Advanced Technology BAT effluent limitations and two tiers of Voluntary Advanced Technology NSPS, which together form the Voluntary Advanced Technology Incentives Program. The three BAT tiers are labeled Tier I, Tier II and Tier III; the two NSPS tiers are labeled Tier II and Tier III. Tier III is the most stringent. The technology bases and ultimate tier limitations of BAT Tiers II and III are identical to NSPS Tiers II and III.

3.1 Tier I

3.1.1 Tier I Technology Basis

EPA determined that the most appropriate technology basis for Tier I was BAT Option B. This option was considered for baseline BAT limitations but rejected because it was not economically achievable on an industry-wide basis (see the discussion of BAT Option B in Section VI.B.5.a(5) of the preamble to the promulgated regulation). The Option B/Tier I technology basis is extended delignification with complete substitution of chlorine dioxide for elemental chlorine, and recycle to chemical recovery systems of all pulping area filtrates generated prior to bleaching. EPA selected this technology basis because it is available today, it is economically achievable for mills voluntarily choosing to implement it (see Section IX.A.6 of the preamble), and because it represents an important step in the direction of a minimum-impact mill. EPA selected this technology basis for the threshold level of the Advanced Technology program to provide maximum encouragement to as many mills as possible to achieve the performance of at least Tier I of the Advanced Technology program. Establishing the Tier I technology basis at a more advanced level could discourage mills from making additional capital investments beyond those necessary to achieve the baseline BAT. This could undermine a primary goal of the incentives program, which is to achieve the greatest environmental results possible consistent with mills' capital investment cycles. In addition, the technology basis of Tier I is far enough beyond the baseline BAT to justify the incentives that accrue from meeting the associated Tier I limits.

3.1.2 Tier I Performance

3.1.2.1 AOX

EPA's analytical database contains final effluent AOX data for nine mills with Option B technology [10]. These data are presented in Table 3-1, in order of descending AOX effluent load. Data are available for mills using softwood furnish only, and mixed softwood and hardwood furnish.

Note that Table 3-1 lists the data that were used to define the performance of BAT Option B, as well as data from three additional mills: 106, 108 and 111. Data from these three mills were not used to develop Option B limits because they reflect a mixed hardwood and softwood furnish. As described further in Data Available for Limitations Development for Toxic Nonconventional Pollutants (10), EPA developed AOX limits for Options A and B, based on softwood data only. EPA reasoned that effluents from softwood pulping operations have higher pollutant loadings than effluents from hardwood pulping, and therefore the limits should be based on softwood data. Thus, mills pulping hardwood or a mixture of softwood and hardwood will be able to meet the mandatory limits based on softwood pulping and bleaching data.

To establish Tier I limits, EPA added data from the three mixed furnish mills, because EPA wanted to evaluate the full range of likely furnishes and operating conditions at mills using extended delignification technology. The Tier I limits for AOX are intended to reflect the performance level that EPA believes mills employing extended delignification technology can achieve without great difficulty, in order to encourage as many mills as possible to move beyond baseline BAT and implement extended delignification technologies. Therefore, EPA established the Tier I AOX limitation by examining the range of performance demonstrated by mills with Option B/Tier I technology. The goal of this examination was to identify the AOX level that would encourage as many mills as possible to participate in the

Table 3-1

Final Effluent AOX Data for Mills with Option B Technology Used to Establish Tier I AOX Performance Level

Mill	Furnish	Prebleaching Kappa Number	Kappa Factor	Number of Data Points	Average Final Effluent AOX (kg/kkg)
NCASI Mill G	softwood	15	0.405	3	0.33
107	softwood	20[a]	0.180	4	0.28
111	softwood and hardwood	HW - 13 SW - 15	HW - 0.363 SW - 0.295	3	0.27
120	softwood	18	0.194	232	0.23
108	softwood and hardwood	15[b]	Not available	3	0.18
106	softwood and hardwood	HW - 11 SW - 16	HW - 0.179 SW - 0.314	6	0.15
109	softwood	13	0.200	3	0.12
101	softwood	15-16	0.209	8	0.12
110	softwood	19	0.189	3	0.081

(a) Prebleaching kappa number for Mill 107 was incorrectly reported as 25 in DCN 13951.
(b) Average kappa number for softwood and hardwood bleach lines.

Voluntary Advanced Technology Incentives Program, but would also preclude mills from participating if they do not have Option B/Tier I technology.

Upon examination of this database, as it existed in early 1996, EPA indicated in the July 15, 1996 Notice of Availability that it had preliminarily defined the long-term average AOX performance of Tier I as less than or equal to 0.3 kg/kkg (see the July 1996 Background Information Supporting Incentives [11]). EPA subsequently received comments on this preliminary determination from industry representatives, indicating that a lower long-term average AOX value of 0.26 kg/kkg would serve as a more appropriate basis for the Tier I performance level.

EPA reexamined the available data and concluded that a long-term average of 0.26 kg/kkg is the appropriate Tier I AOX performance level. This level is inclusive of the range of performance demonstrated by the mills with Option B/Tier I technology listed in Table 3-1. EPA promulgated an annual average limit (equivalent to the long-term average) and is also promulgating a daily maximum limit based on this long-term average performance multiplied by an appropriate variability factor. The variability factors used were developed for BAT Option B, which has the same underlying technology basis as Tier I. The development of the variability factors is discussed in the Statistical Support Document [12]. Annual average limits, daily maximum limits, and the 30-day and 1-day maximum variability factors are presented in Table 3-2. While monthly average limits are not promulgated for AOX at Tier I, a 30-day variability factor and corresponding monthly average performance level is shown in Table 3-2 for comparison purposes.

Table 3-2

Tier I AOX Limits and Performance Levels for ECF Fiber Lines

Option	Long-term Average (Annual Average Limit) (kg/kkg)	30-day Variability Factor	1-day Variability Factor	Monthly Average Performance (kg/kkg)	Daily Maximum Limit (kg/kkg)
Tier I	0.26	1.31	2.28	0.34	0.59

EPA compared the monthly average performance level listed in Table 3-2 to the average AOX value for each mill listed in Table 3-1. Most of the mill datasets have either 3 or 4 data points, the approximate number of samples normally collected in the course of a month under a weekly sampling regimen. The average for each mill in Table 3-1 falls below the monthly average performance level, confirming that mills with Option B/Tier I technology will be able to comply with the Tier I AOX limits. Note that NCASI Mill G, which had the highest average AOX level, bleached with a kappa factor of over 0.4 when the AOX data were collected. Since EPA and other researchers have found that AOX is a function of kappa factor (6)[13], EPA anticipates that this mill could significantly lower its AOX discharges if it were to bleach with a kappa factor of 0.2, similar to other mills in the dataset.

3.1.2.2 Kappa Number

EPA examined the performance of extended cooking and oxygen delignification in reducing the kappa number into bleaching. Data used in this evaluation are from the EPA BAT baseline database [14] and from the EPA analytical database [15]. Note that these two databases are not completely independent; data for certain mills are included in both databases.

The Tier I BAT limitations for kappa number of unbleached pulp are 20 for softwoods and 13 for hardwoods, measured on a long-term average basis. EPA chose these values because they reflect the capability of extended delignification technologies. While these kappa numbers are at the upper end of the range of values achieved by extended delignification technologies, they appear to distinguish mills that employ these technologies from mills that use conventional pulping technologies. Because kappa number is an important process parameter, monitored by mills on an ongoing basis, EPA is not establishing minimum monitoring requirements for kappa number. Permit writers maintain the authority to establish monitoring frequencies on a best professional judgment basis.

Softwood Kappa Number

For fiber lines processing softwood, EPA has concluded that a kappa number into bleaching of 20 or below is readily achievable, and is indicative of mills with effectively operated extended delignification technology in place. Further, fiber lines employing conventional pulping alone cannot be operated economically to achieve a brown stock pulp kappa number of 20.

Data showing the relationship of pulping technology to kappa number for fiber lines in the BAT baseline database are presented in Figure 3-1. The data are presented for fiber lines using extended cooking, oxygen delignification, or both technologies. Data are also presented for fiber lines using conventional pulping technology where these lines occur at mills that also have fiber lines with extended cooking and/or oxygen delignification. As shown on Figure 3-1, mills with oxygen delignification, and extended cooking and oxygen delignification, uniformly achieve an unbleached kappa number below 20. Mills with extended cooking can achieve an unbleached kappa number below 20, if the mill chooses to operate in that range. Fiber lines at the mills using conventional pulping technology achieve unbleached kappa numbers of 22 and above.

Similar data are available in the EPA analytical database. Data showing the relationship of pulping technology to unbleached kappa number at mills in this database are presented in Figure 3-2. As above, all fiber lines that use extended cooking and oxygen delignification or oxygen delignification alone to achieve an unbleached kappa number below 20. Mills in this database using extended cooking technology alone are not pushing the technology; they achieve kappa numbers ranging from 22 to 27. All mills in this database using conventional pulping technology achieve unbleached kappa numbers of 23 and above.

Figure 3-1. Softwood Kappa Number vs. Pulping Technology, BAT Baseline Database

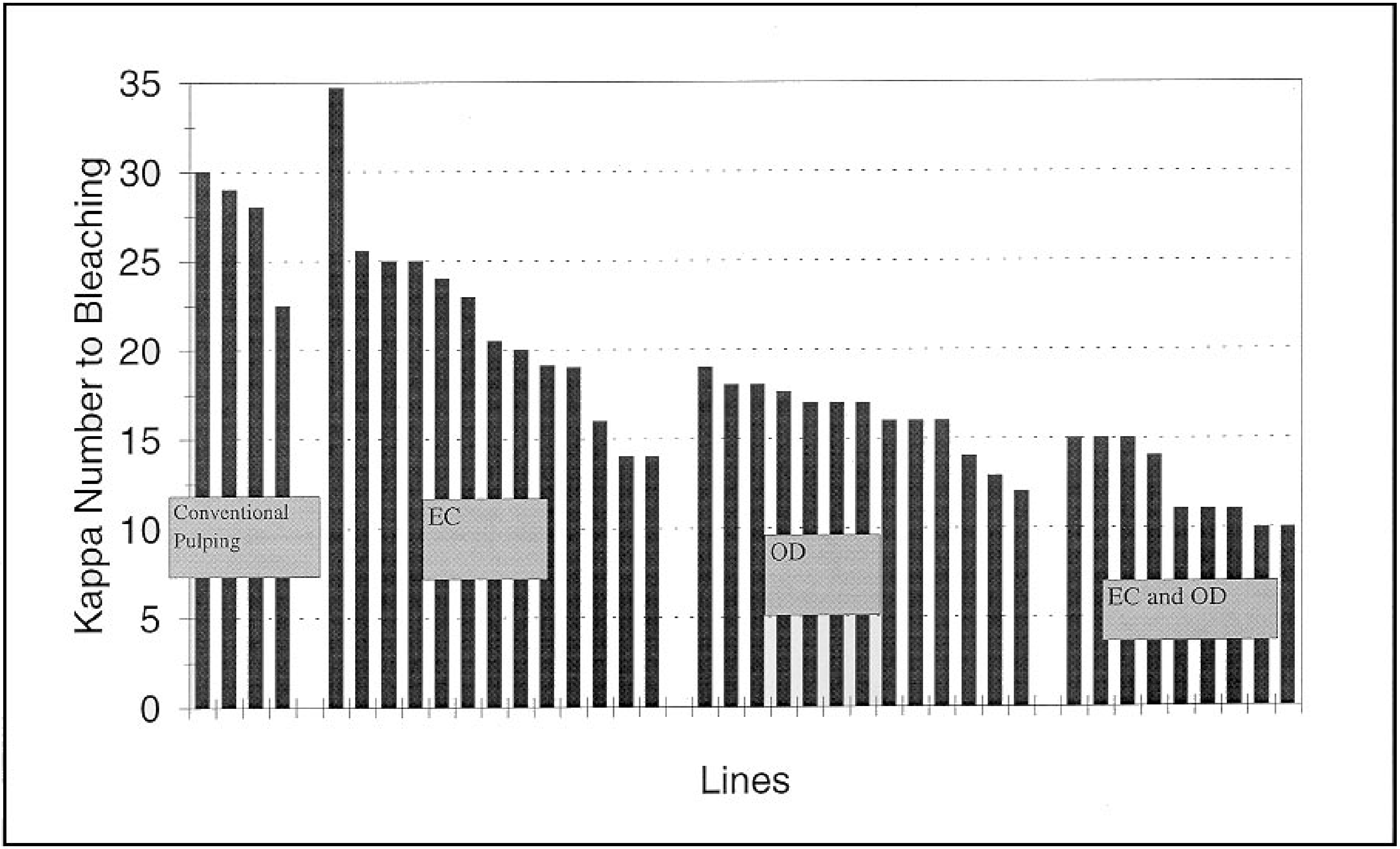
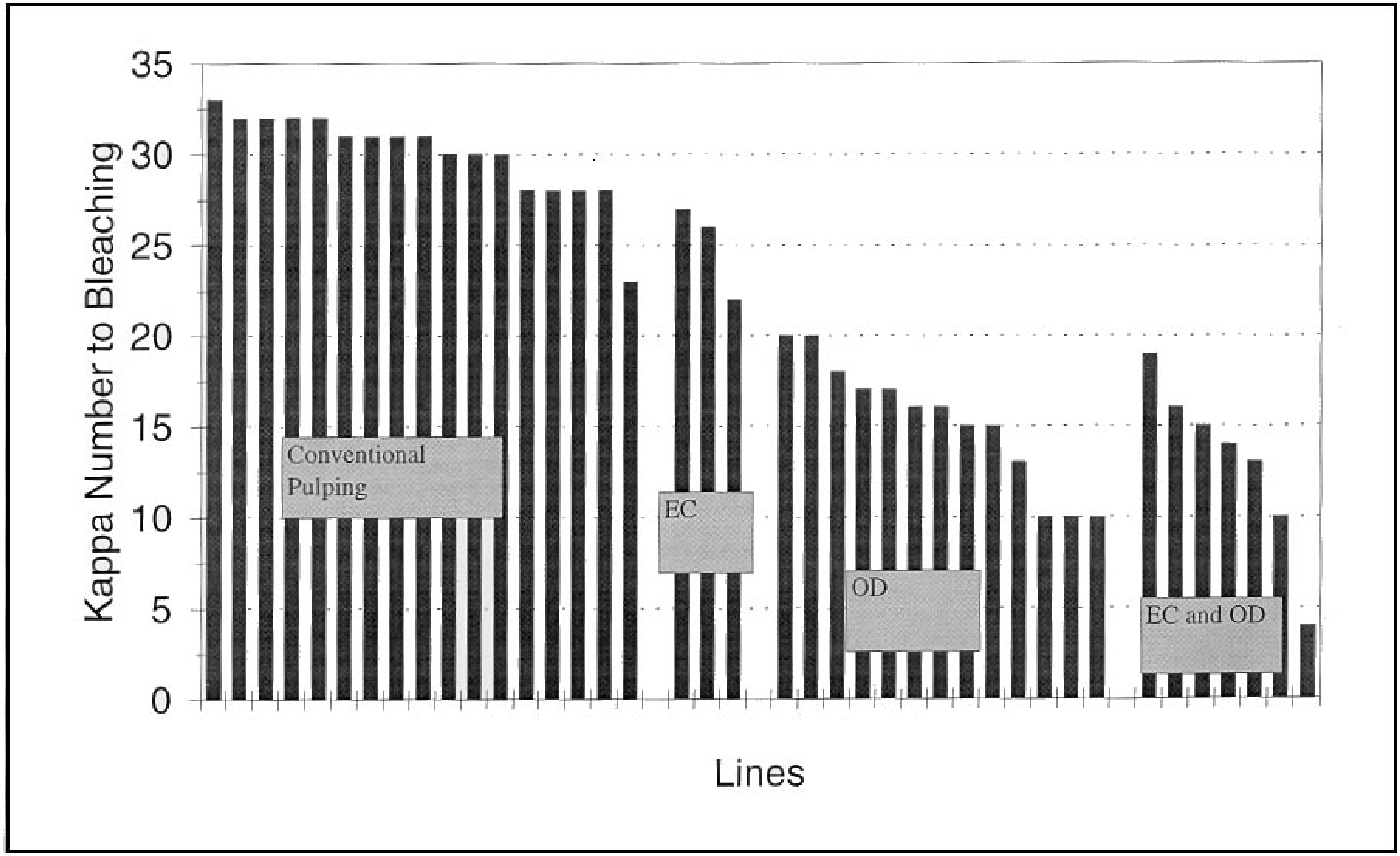


Figure 3-2. Softwood Kappa Number vs. Pulping Technology, EPA Analytical Database



Hardwood Kappa Number

For fiber lines processing hardwood, EPA has concluded that an unbleached kappa number into bleaching of 13 or below is readily achievable, and is indicative of mills with effectively operated extended delignification technology in place.

Hardwood fiber line data similar to the softwood fiber line data presented above are available in the same databases. Data showing the relationship of pulping technology to kappa number for hardwood fiber lines in the BAT baseline database are presented in Figure 3-3. The data are presented for fiber lines using extended cooking, oxygen delignification, or both technologies. Data are also presented for fiber lines using conventional pulping technology where these lines occur at mills that also have fiber lines with extended cooking and/or oxygen delignification. As shown on Figure 3-3, mills with oxygen delignification, and extended cooking and oxygen delignification, uniformly achieve an unbleached kappa number of 13 or below. Mills with extended cooking can achieve an unbleached kappa number below 13, if the mill chooses to operate in that range. Fiber lines at mills using conventional pulping achieve unbleached kappa numbers of 13 and above.

Similar data are available in the EPA analytical database. Data showing the relationship of pulping technology to unbleached kappa number at hardwood mills in this database are presented in Figure 3-4. All fiber lines in this database using extended delignification technology achieve an unbleached kappa number of 13 or below. Only two of 14 fiber lines using conventional pulping technology achieve kappa numbers below 13.

When coupled with a long-term average AOX discharge value of 0.26 kg/kkg, discussed in the previous section, requirements on kappa number into the bleach plant should further EPA's goal of promoting the use of extended delignification technologies.

Figure 3-3. Hardwood Kappa Number vs. Pulping Technology, BAT Baseline Database

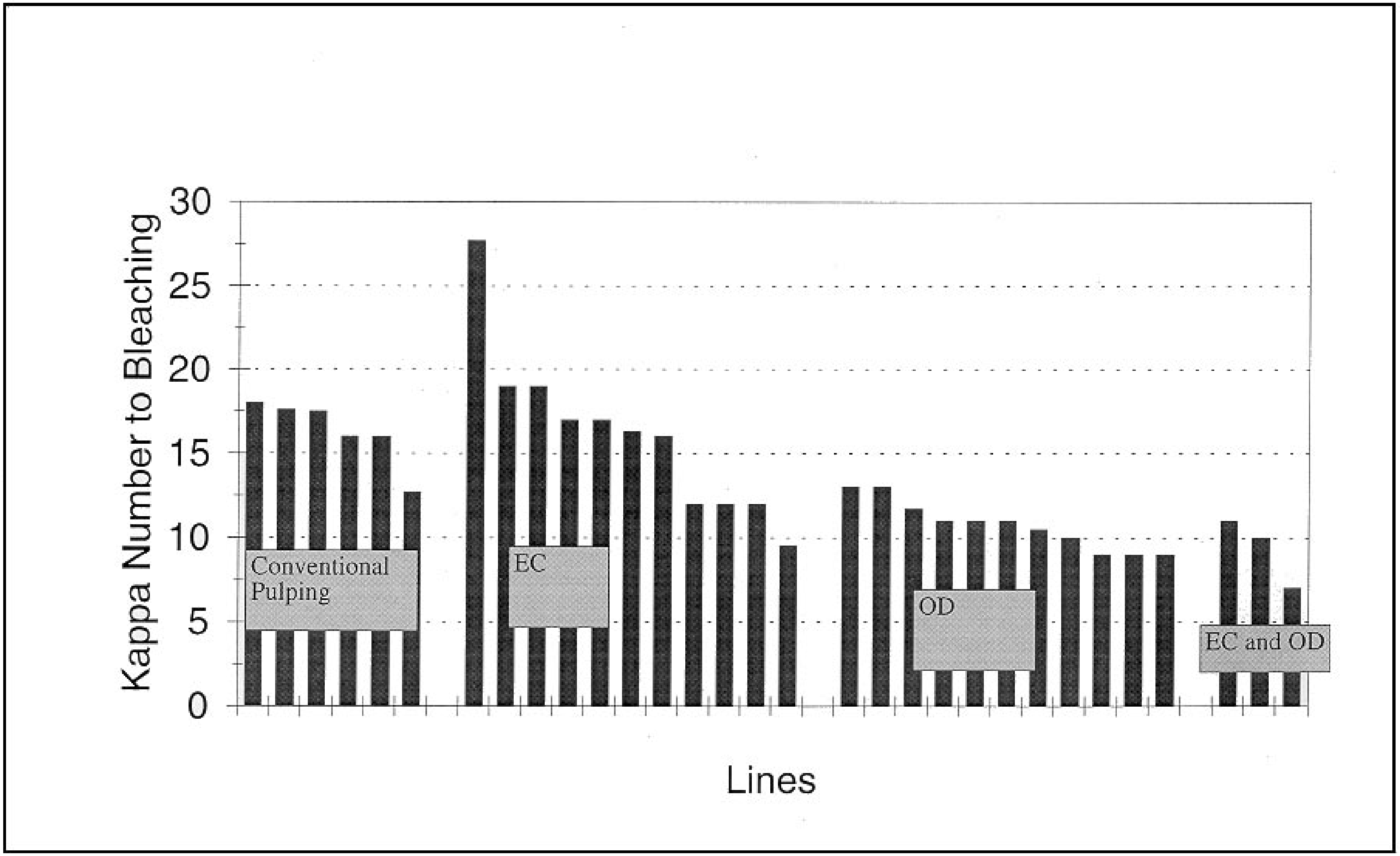
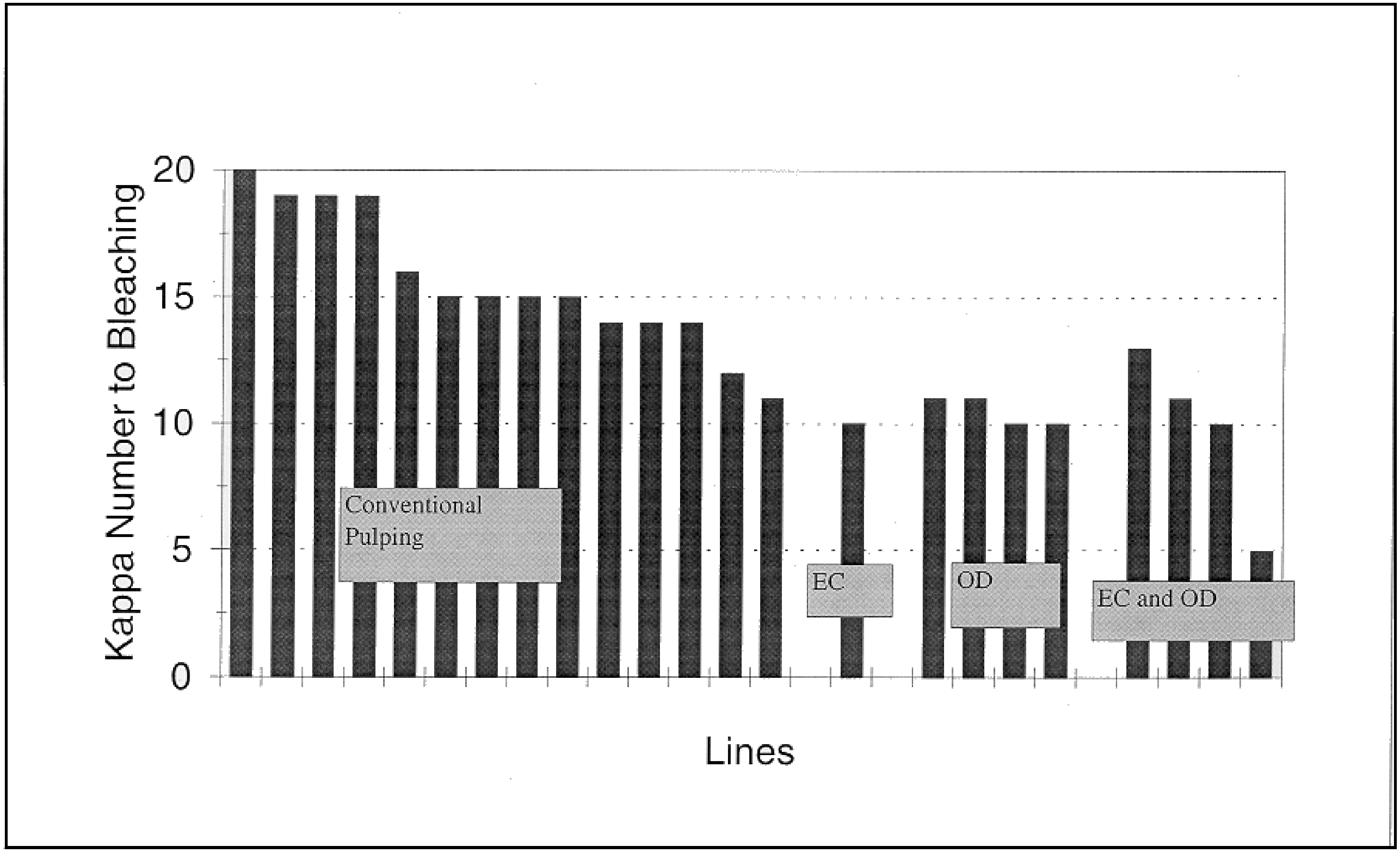


Figure 3-4. Hardwood Kappa Number vs. Pulping Technology, EPA Analytical Database



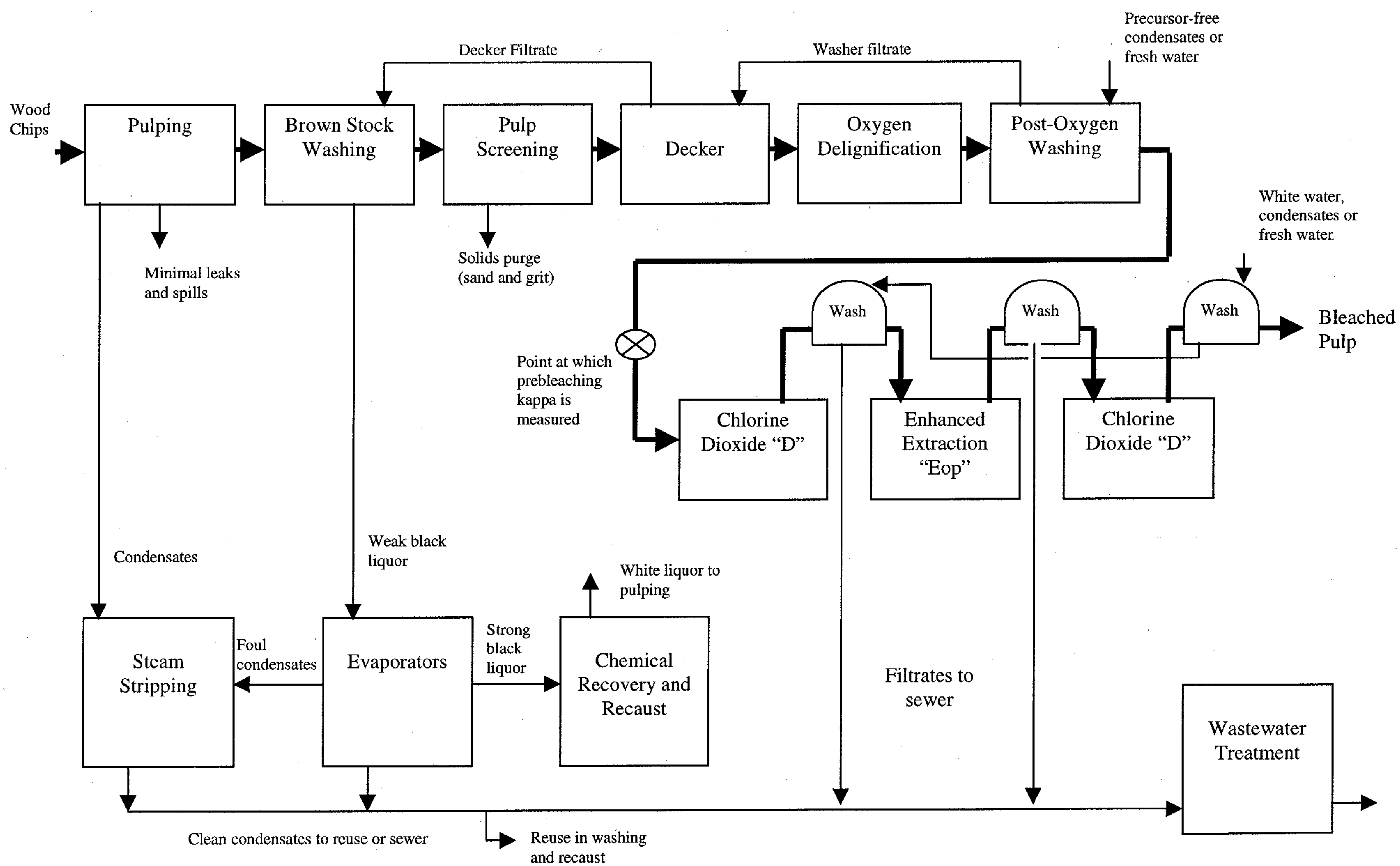
3.1.2.3 Pulping Area Filtrate Recycle

EPA's requirement to recycle pulping area filtrates is a critical step in reducing overall mill wastewater discharges and in eliminating a significant source of weak black liquor discharge that would otherwise go to the mill's wastewater treatment plant. Recycling of pulping area filtrates to the chemical recovery cycle prevents the discharge of weak black liquor, which contains inorganic pulping chemicals and dissolved wood substances. The dissolved wood substances include polynuclear aromatic hydrocarbons, degraded carbohydrates, low-molecular weight organic acids, and wood extractives (resins and fatty acids). The toxicity of the materials contained in black liquor is well documented (9). In addition to the reductions in the discharges of toxic materials, recycle of pulping area filtrates also results in reductions in mill BOD, COD, and color discharges.

Tier I requires the recycle of all filtrates prior to the point where kappa into bleaching is measured. As depicted on Figure 3-5, this includes the closure of the screening system, so that all wash water flows countercurrent from the decker to the mill's chemical recovery system. Screening removes unacceptable material from the main pulp stream. The fibrous portion of this material is returned to the pulping process or is burned to recover fuel value in on-site boilers. There will be some solid material, typically sand and grit, that must be discharged from the closed screening system. This solid material will carry a minimal amount of water with it, typically under 0.01 m^3/kkg. About 50 percent of U.S. bleached kraft mills currently employ closed screening (14).

While not a performance criteria that would be an NPDES permit limitation, EPA assumes that mills choosing to participate at Tier I will implement BMPs equal to or more stringent than those necessary to comply with the minimum BMP requirements in 40 CFR 430.03.

Figure 3-5. Tier I Configuration



As depicted in Figure 3-5, if oxygen delignification is employed, the filtrates from the post-oxygen washer(s) must be recycled to chemical recovery (typically after it is used as screening dilution water). However, it should be noted that the flow scheme depicted in Figure 3-5 is not the only way to meet the filtrate recycle criterion of Tier I.

3.1.2.4 Specification of Tier I Technology

EPA considered whether it would be better to specify acceptable technologies that would qualify a mill for entry into Tier I, rather than to limit the kappa number. EPA rejected this approach because it would inhibit development of equivalent technologies that EPA cannot foresee today and because it is inconsistent with the traditional performance-based structure of technology-based effluent limitations under the Clean Water Act. EPA determined that specifying a kappa number limit, rather than specific technologies, provides industry with the most flexibility, and will ultimately lead to most innovative development of advanced technologies. The kappa number limit is consistent with the overall pollution prevention goals of the incentives program. Technologies that reduce kappa into bleaching, coupled with the recycle of pulping area filtrates, return inorganic pulping chemicals as well as dissolved wood substances to the recovery cycle and reduce bleaching chemical requirements. In addition, the kappa number limit captures a range of extended delignification technologies, perhaps some yet to be developed, rather than requiring any specific technology. Mills can use their ingenuity to comply with the kappa number limit. Considering resources and capabilities available to them, and mill specific requirements, they are likely to develop more efficient and cost-effective methods to achieve the Tier I limitations than EPA would compel through the use of a prescriptive technology requirement under Tier I.

3.1.3 Tier I Fiber Line Configurations

Many fiber line variations are available to achieve the Tier I limits. EPA expects that the most common approach will be to use the technology basis of BAT Option B. This includes extended delignification (accomplished by delignification and/or extended cooking followed by complete substitution of chlorine dioxide for elemental chlorine) as well as the following nine elements:

- Adequate chip thickness control;
- Use of dioxin- and furan-precursor-free defoamers (water-based defoamers or defoamers made with precursor-free oils);
- Effective brown stock washing (i.e., washing that achieves a soda loss of less than or equal to 10 kg Na_2SO_4 per kkg of pulp (equivalent to 99 percent recovery of pulping chemicals from the pulp));
- Elimination of hypochlorite (i.e., replacement of hypochlorite with equivalent bleaching power in the form of additions of peroxide and/or oxygen to the first extraction stage and/or additional chlorine dioxide in final brightening stages);
- Oxygen and peroxide enhanced extraction, which allows elimination of hypochlorite and/or use of a lower kappa factor in the first bleaching stage;
- Use of strategies to minimize kappa factor and dioxin and furan precursors in brown stock pulp;
- High-shear mixing during bleaching to ensure adequate mixing of pulp and bleaching chemicals;
- Closed brown stock pulp screen room operation, such that screening filtrates are returned to the recovery cycle; and
- Efficient biological wastewater treatment, achieving removal of 90 percent or more of influent BOD.

In addition to the above technology elements, mills with Tier I fiber lines (like any Subpart B mill) will need to implement best management practices to prevent or otherwise contain leaks and spills and to control intentional diversions of spent pulping liquor, soap, and turpentine. See 40 CFR 430.03. The major elements of the above mill configuration are shown in Figure 3-5.

Because the Tier I technology basis is equivalent to BAT Option B, the Tier I cost estimates, pollutant load reduction estimates, and non-water quality environmental impact estimates presented in Sections 5, 6, and 7, respectively, are the same as those calculated for BAT Option B.

3.2 Tier II

3.2.1 Tier II Technology Basis

Under Tier II, the AOX performance requirement is a long-term average discharge of 0.10 kg/kkg or less, measured at the end of pipe. In addition, Tier II fiber lines must recycle to the chemical recovery system all pulping area effluents that contain black liquor solids. Tier II fiber lines must also achieve total pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow of 10 m^3/kkg or less reported as an annual average. Tier II mills also must meet limitations for dioxin, furan, chloroform, and the 12 chlorinated phenolic pollutants.

The Tier II technology basis includes all the elements described under Tier I. In addition, Tier II mills will maximize the capability of extended delignification technology, thereby reducing the amount of chlorine dioxide and other chemicals used in bleaching. EPA expects that mills choosing to participate at Tier II will implement stringent BMPs to move toward the elimination of leaks and spills, while also capturing and recycling - rather than discharging - liquors during fiber line disruptions through detailed scheduling of planned outages (e.g., maintenance) and contingency planning for unplanned disruptions. Tier II mills will have evaporators that minimize the amount of black liquor carry over and associated steam strippers, allowing extensive condensate reuse. EPA expects that Tier II mills also will employ improved water reuse within the bleach plant, and may recycle a portion of bleach plant filtrate back through the fiber line to the recovery cycle.

Tier II mills that achieve extensive condensate reuse through steam stripping or other treatments that result in HAP reductions may also be eligible for the "clean condensate alternative", a MACT compliance alternative.

The major differences between the Tier I and Tier II technology basis is that, under Tier II, the degree of delignification prior to bleaching is maximized and additional water conservation and reuse is practiced, further reducing the amount of all pollutants discharged in the mill effluent, including BOD, COD, color, and chlorinated organic pollutants.

Three mills in the United States are approaching the reduced wastewater flow levels required by Tier II. Although the flow volume projected or reported by these mills excludes pulping area or evaporator condensates, which EPA includes within its Tier II flow limitation, EPA expects that, over the next ten or eleven years, condensate reuse strategies and discharge flow reduction technologies will mature to allow mills to achieve the pulping area condensate, evaporator condensate, and bleach plant wastewater flow level included as part of the Tier II limitations.

3.2.2 Tier II Performance

3.2.2.1 AOX

EPA is setting the AOX limit for Tier II based on a long-term average (0.10 kg/kkg) that is currently achieved by the best mills in the industry using components of the Tier II technology basis.

As reported in Table 3-1, EPA's analytical database contains data for six mills that use extended cooking and/or oxygen delignification and ECF bleaching of softwood. Final effluent AOX discharged from these mills ranges from 0.081 to 0.33 kg/kkg. The best three mills achieve a range of 0.12 to 0.081 kg/kkg.

Based on these data, EPA has concluded that a long-term average AOX level of 0.10 kg/kkg reflects the performance of the Tier II technology basis, for mills using ECF-based bleaching. EPA promulgated an annual average limit equivalent to this long-term average, and is also promulgating a daily maximum limit based on this long-term average performance multiplied by an appropriate variability factor. The variability factors used were developed for

BAT Option B. The Option B variability factor forms a rational basis for the Tier II variability factor because it is also based on extended delignification and ECF bleaching technology. It could be argued that since the Tier II limits are lower than the Option B limits, variability under Tier II may be greater than under Option B. EPA considered this but determined that any such effect would be offset by the better process control strategies utilized by mills employing Tier II level technology and more stringent implementation of BMPs, which will result in more uniform pulp characteristics and effluent quality. Therefore, EPA is using the Option B variability factor to represent the expected AOX variability under Tier II. Annual average limits (equivalent to the long-term average), daily maximum limits, and the 1-day maximum variability factor are presented in Table 3-3.

Table 3-3

Tier II AOX Limits and Performance Levels for ECF Mills

Option	Long-term Average (Annual Average Limit) (kg/kkg)	1-day Variability Factor	Daily Maximum Limit (kg/kkg)
Tier II	0.10	2.28	0.23

EPA collected and analyzed bleach plant effluent samples from two kraft mills that produce TCF bleached pulp during four sampling episodes: 112, 113, and Mill 114 Episodes A and B. The results from Episodes 112 and 113 are from two separate bleach lines at the same mill. At the time of sampling, the mill operated two bleach lines (one for hardwood and one for softwood), each of which alternated between ECF or TCF bleached pulp production. Thus, while the hardwood line was operating TCF, the softwood line was operating ECF, and vice versa. During Episode 112, wastewaters from TCF bleaching of softwood pulp were collected while ECF hardwood and TCF softwood pulps were produced. During Episode 113, wastewaters from TCF bleaching of hardwood pulp were collected while TCF hardwood and ECF softwood pulps were produced. Mill 114 produced only softwood TCF pulp during two separate sampling periods identified as Episodes A and B.

Both mills use oxygen delignification and a bleach sequence with a chelant stage followed by a series of peroxide stages. Mill 112/113 also uses extended cooking on both fiber lines.

At Mill 112/113, AOX was detected (at concentrations up to 2,830 µg/L compared to the method minimum level of 20 µg/L) in each bleach plant filtrate sample collected during production of TCF hardwood and softwood pulps. The average mass loading of AOX in these bleach plant effluents was 0.015 kg/kkg for hardwood and 0.0021 kg/kkg for softwood. These low, but detectable, AOX loadings are likely the result of the frequent swings between ECF and TCF that occur at this mill (i.e., as a result of incomplete flushing of the bleach plant between campaigns) or cross-over of some chlorine-containing wastewater from one line to the other (because chlorine dioxide was generated on site and used on one line while each TCF sampling campaign occurred on the other line). Another possible source of minimal background levels of AOX is the use of chlorine-containing compounds to disinfect the mill raw water supply. EPA did not determine, however, if this mill uses chlorine containing compounds to disinfect its raw water supply.

At Mill 114, AOX was detected in the bleach plant effluent (at 22 µg/L in the acid filtrate and at 69 µg/L in the alkaline filtrate) on the first day of Episode A but it was not detected in any bleach plant filtrate sample collected on any other day during Episodes A or B at this mill. This mill used chlorine to disinfect the mill water during Episode A (but not during Episode B), which could have led to a detectable concentration of AOX in bleach plant effluent. A few days prior to the start of the TCF bleaching campaign (Episode A), the mill completed a campaign of chlorine-based bleaching. The fact that a detectable amount of AOX was present in only the samples collected on the first sampling day may be a result of incomplete flushing of the bleach plant between the end of the chlorine-based bleaching campaign and the TCF campaign. The results from the other samples from this mill show that AOX is consistently not present above the minimum level of the analytical method. From these data, EPA concluded that AOX is not generated at levels above the minimum level when TCF bleaching is performed on a consistent, steady-state basis, as would be the case at a fiber line certified to be TCF.

3.2.2.2 Pulping Area Filtrate Recycle

Tier II includes a requirement to recycle pulping area effluents that contain black liquor solids, for the same reasons discussed in Section 3.1.2.3.

3.2.2.3 Discharge Flow

Under the Tier II BAT limitations, mills are required to maintain total pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow of 10 m^3/kkg or less, reported as an annual average. EPA is setting an Advanced Technology limit on flow within the plant because the model technologies EPA expects to be the basis of Tier II and Tier III consist primarily of process changes, not end-of-pipe technologies; measuring the effectiveness of the flow minimization technologies after bleach plant and condensate flow is commingled with flows from other parts of the mill, (i.e., at the end of the pipe) is not feasible. See 40 CFR 122.44(h). Once flow measurement equipment is installed and operated, EPA expects mills will monitor flow on an ongoing basis, as they would any other important process parameter. EPA is not establishing minimum monitoring frequencies for flow or calibration frequencies for flow measurement devices in this regulation. Permit writers maintain the authority to establish monitoring and calibration frequencies on a best professional judgment basis. See 40 CFR 430.02.

<u>Bleach Plant Effluent</u>

Bleach plant discharge flows for bleached kraft mills in EPA's analytical database range from 6.7 to 88.6 m^3/kkg. The median value is 24.5 m^3/kkg. Twelve mills operate bleach lines with flows between 10 and 20 m^3/kkg using a range of bleaching technology from conventional bleaching with chlorine and hypochlorite to TCF bleaching. Several mills worldwide, summarized in Table 3-4, currently have bleach plant effluent flows below 10 m^3/kkg. These mills are generally advanced technology mills with an active research interest in technology that minimizes effluent.

Table 3-4

Mills Using Minimum-Effluent Technology

Mill	Technology	Bleach Plant Discharge Flow (m^3/kkg)	Comments	Source
Champion, Canton, NC	OD, ECF, BFR™-closed cycle	8 (with further reduction planned)	Mill uses a $OD_1E_{op}D_2$ bleach line. E_{op} filtrate recycled to post-oxygen washing. D_1 filtrate reused as bleach plant wash water after treatment by metals removal process (ion exchange). D_2 filtrate is currently sewered; Champion will experiment with closing this stage by recycling filtrate to the E_{op} washer. Mill chloride and potassium balance is maintained by a chloride removal process (crystallization) performed on precipitator ash. A portion of the filtrate from the crystallization process is sewered to provide the potassium and chloride purge.	(5), (16),(17), (20)
Metsa-Rauma, Finland	OD,Ozone,TCF	4	Greenfield mill started up in March 1996. Total mill discharge of 10-15 m^3/kkg at start-up, bleach plant discharge of 4 m^3/kkg. Provision for total mill discharge to be reduced to 5 m^3/kkg.	(5),(18)
Louisiana-Pacific, Samoa, CA	OD, TCF	6.8	Mill uses a QP_oPPP sequence; the only discharge is from the Q stage. Plan to achieve discharge of 2-3 m^3/kkg once bleach plant water balance is optimized and recausticizing area improvements are made to allow partial reuse of Q stage discharge.	(5),(15)
Union Camp, Franklin, VA	OD, Ozone, ECF	9.4	Mill operates a OZE_oD sequence. Filtrates from O, Z, and E_o stages are sent back to recovery via countercurrent washing. Part of the Z stage filtrate is bled to sewer to prevent scaling; the D-stage is open to sewer.	(5)
Modo, Husum, Sweden	HW-OD,Ozone,ECF SW- OD, ECF	HW-5 SW-8	Hardwood line has a four stage sequence. Countercurrent filtrate recycle is used. First two stages are closed, last two are open to the sewer. Softwood line has a three-stage sequence. Filtrate is recovered from the first D stage and the alkaline stage. Second D stage filtrate is sewered.	(5),(19)
SCA, Ostrand, Sweden	OD,Ozone,TCF	7	Designed to achieve 5 m^3/kkg.	(5)
Sodra Cell, Morrum, Sweden	OD, TCF	8 (planned)	Planned discharge target once bleach plant rebuild is complete.	(5)

References: [16],[17],[18],[19]

Three mills in the United States, each using a different technology approach, achieve bleach plant discharge flow rates under 10 m^3/kkg. The Champion, Canton, North Carolina mill has implemented BFR™-closed cycle technology on its softwood line, and achieved a bleach plant discharge flow rate of 8 m^3/kkg as of March 1997 [20]. The Champion fiber line uses oxygen delignification and ECF bleaching. The Union Camp mill in Franklin, Virginia uses oxygen delignification, ozone, and ECF-based bleaching and achieves a bleach plant discharge flow of 9.4 m^3/kkg (5). The Louisiana Pacific mill in Somoa, California uses a TCF sequence based on oxygen delignification and peroxide bleaching, and discharged 6.8 m^3/kkg of bleach plant effluent as of 1995 (5). Considering the current bleach plant discharge status of these leading mills, EPA determined that 10 m^3/kkg was an appropriate Tier II long-term average discharge flow limit for bleach plant filtrate and pulping area and evaporator condensates. While pulping area and evaporator condensates are not included in the flow totals provided above, these and other mills choosing Tier II will have 10 years to develop and implement the technical approaches necessary to achieve the flow limits. Opportunities to reduce pulping area and evaporator condensate discharges are discussed further below.

<u>Pulping Area and Evaporator Condensates</u>

Modern kraft mills generate approximately 10 m^3/kkg of pulping area and evaporator condensates [21222324], as totaled below:

<u>Condensate Stream</u>	**<u>Volume (m^3/kkg)</u>**
Clean evaporator condensates	8
Dirty condensates	
Foul evaporator condensates	1.2
<u>Digester condensates</u>	<u>0.7</u>
Total condensates	` 10

Reference (23)(24)

This dirty condensate is frequently steam stripped to remove reduced sulfur compounds (TRS) and methanol. The relative volume of condensate flow compared to other sources of process water discharge in a modern mill using ECF bleaching technology is shown below (adapted from 24):

Mill Area	**Discharge Flow (m^3/kkg)**
Debarking	1.5 - 4.0
Pulping Area Condensates	10
Bleaching	16
Pulp Drying	9

Some of these flows may be recycled; for example, white water for pulp drying may be reused for bleach plant washing, and condensates may be reused for brown stock washing or as make-up water in recausticizing.

Dirty condensates contain many impurities, including alcohols (primarily methanol), ketones, terpenes, sulfur compounds, phenolics, and organic acids, at concentrations between trace levels and 1 percent by weight. Thus, they can contribute significantly to many of the adverse environmental effects of kraft mill operations. Foul condensates have also been linked to toxicity in kraft mill effluent, even after treatment in a 5-day retention aerated lagoon [25].

Treatment and reuse of condensates avoids the discharge of pollutants contained in condensates, described above. In addition, reuse of condensates is an important component of water usage and heat conservation programs in a kraft mill operation. Increasing the quantity of condensates reused and, for some reuse applications, improving the quality of condensates via treatment offers the potential for further reduction in water usage rates and atmospheric emissions of volatile organic compounds such as methanol from unit processes at which condensates are reused (22). The latter is the rationale behind the clean condensate alternative to MACT compliance.

Water conservation that results from condensate reuse will lower mill consumption of fresh water resources and reduce mill wastewater discharge volume. End-of-pipe treatment system efficiency for all pollutants will increase with reduced process water throughput. For example, suspended solids and BOD in effluent generally decrease in proportion to the amount of water saved [26].

Most mills reuse some condensates, either steam-stripped condensates or clean evaporator condensates, which are a ready source of hot water. EPA observed during engineering site visits several mills that had virtually eliminated the discharge of pulping area and evaporator system condensates through reuse of clean and steam-stripped dirty condensates [272829]. Several mills described in NCASI Technical Bulletin 702, which characterizes kraft mill condensates, are also shown to practice virtually complete condensate reuse [30]. Typical areas for reuse include brown stock washing and recausticizing (22).

Condensates should be free of dioxin and furan precursors if they are used for pulp washing just prior to bleaching, such as in post oxygen washing. It has been hypothesized that condensates inadequately treated to remove volatile black liquor components, but used to wash oxygen delignified pulp, are a source of precursors.

A key factor to consider in evaluating condensate reuse at advanced technology, minimum-impact mills is that increased bleach filtrate recycle eliminates one of the traditional primary opportunities for condensate reuse. At advanced technology mills, bleach filtrates are used as make-up water and wash water on the brown stock side of the fiber line, usually on the post-oxygen washer. When this is the case, condensates cannot be used for the same purpose. The challenge at mills developing closed-cycle technology is to find ways to reuse condensates as beach plant wash water, or in other areas of the mill.

For use in bleach plant washing, condensates need to be free of sulfur compounds and color to consistently and reliably use them, because the slightest contamination in the condensate will create a foul odor or other undesirable properties in the pulp. Additional energy-efficient treatment of condensates, beyond the typical level of steam stripping, may be required before they can be fully reused for bleaching, or in other areas of the mill. Active research is ongoing in this area; in-plant biological treatment and additional steam stripping are being explored by the industry and technology vendors as possible treatments (22)(23)(24).

In the case of in-plant biological treatment, pulp mill condensates were hard-piped to a pure-oxygen activated sludge process in a mill-scale trial, and bench-scale studies of activated sludge treatment of evaporator condensates have been conducted. The results of these studies suggest that biotreatment of kraft mill condensates to an acceptable quality for reuse is feasible, and the cost of such treatment is comparable to the cost of control of vent gases from vacuum drum brown stock washer systems (22). Steam stripping has been used for years to remove reduced sulfur compounds and methanol from digester area condensates and the high waste load fraction of foul evaporator condensates. Recent research has focused on treating a greater quantity of the evaporator condensate, not just the high waste load fraction, to obtain condensate of sufficient quantity and quality to use it for bleach plant washing (23). Such an approach is most energy efficient when the stripper is directly integrated between evaporator effects in the evaporation plant (24).

Technical progress is rapidly advancing in this area, however. The Metsa Rauma mill in Finland, a greenfield mill that began operation in March 1996, reuses clean and steam-stripped foul condensates for bleach plant washing [31]. Sodracell prefers condensates over fresh water for bleach plant washing, because metals concentrations in the condensates are lower than in fresh water [32].

Considering ongoing research efforts and progress made to date in reusing pulping area and evaporator condensates for bleached pulp washing and in other mill applications, and in view of the 10-year development and implementation horizon for Tier II limits, EPA has determined that the appropriate Tier II flow limitation is a combined discharge of 10 m^3/kkg or less of bleach plant filtrate and pulping area and evaporator condensate. EPA believes it is appropriate to include condensates as part of the specified wastewater flow volume because technologies are now becoming available that allow for their recycle and reuse; use of these technologies therefore ensures that the cumulative volume of wastewater flow is reduced to the greatest extent possible.

Reuse of condensates is consistent with a MACT compliance alternative known as the “clean condensate alternative”. See 40 CFR 63.447. This alternative focuses on reducing

HAP emissions throughout the mill by reducing the HAP mass in condensate streams that are recycled to other process areas in the mill. By lowering the HAP mass loading in the recycled streams, by treatment such as steam stripping, less HAP will ultimately be volatilized to the atmosphere. Reducing the HAP content of recycled condensates can be used as a compliance alternative to the kraft pulping standards for the subject equipment in the high-volume, low-concentration (HVLC) system. To do so, a mill must demonstrate that the total HAP emissions reductions achieved as a result of condensate treatment are equal to or greater than the total HAP emission reductions that would have been achieved by compliance with the kraft pulping system standards for equipment in the HVLC system. This alternative facilitates the segregation, treatment, and reuse of condensates and thus will assist mills in achieving the wastewater flow objectives. Inclusion of pulping and evaporator condensates in the Tier II flow limitations therefore is consistent with the "clean condensate" MACT compliance alternative and will promote flow reduction through recycle and reuse of the greatest possible volume of process wastewater. In addition, under the promulgated MACT standards, EPA has excluded specific sources at kraft mills that burn condensates derived from steam stripper overhead vent gases from RCRA, further facilitating steam stripping of condensates.

Compliance with the 10 m^3/kkg limit should be assessed on an annual average basis. Instantaneous discharge flow measurements will vary, and during upset conditions could be significantly higher. Part of the challenge in achieving this limit will be to avoid upset conditions and maintain steady-state conditions in the mill water balance so this annual average discharge flow limit can be achieved. It is anticipated that Tier II mills will capture and recycle - rather than discharge - liquors during fiber line disruptions through detailed planning of maintenance outages and contingency planning for unexpected disruptions.

3.2.3 Tier II Fiber Line Configurations

Many potential approaches are available to achieve the Tier II limitations, and more are likely to be developed over the next 10 years. Two of these potential approaches are presented below. The first relies on oxygen delignification and 100 percent chlorine dioxide substitution for chlorine, and is referred to in this document as the Tier II - ECF configuration. The second is based on oxygen delignification and ozone bleaching, with some chlorine dioxide used for final brightening. A mill using this approach could ultimately convert to TCF operation by using peroxide for final brightening. This is referred to in this document as the Tier II - Toward TCF configuration. Cost estimates, pollutant load reduction estimates, and non-water quality environmental impacts presented in Sections 5, 6, and 7, respectively, are based on a model mill converting to these two configurations.

<u>Tier II - ECF Configuration</u>

To comply with Tier II criteria, a mill which preferred ECF technology would probably have all of the elements described under Tier I, as well as the following characteristics, although other process options exist, and more can be expected to be developed over the next few years.

- Two-stage oxygen delignification and/or extended cooking with oxygen delignification to achieve a kappa number into bleaching of 10 to 12 for softwood and 8 to 10 for hardwood (this facilities use of a lower chlorine dioxide application rate, enabling the mill to achieve the AOX limitation);

- Improved water reuse within the bleach plant, including partial recycle of E_{op} stage filtrate to post-oxygen washing;

- An evaporator upgraded to segregate condensates effectively, integral stripper, and carryover of black liquor solids below 5 ppm (expressed as Na); and

- Best management practices to prevent or otherwise contain leaks and spills to the maximum extent feasible and eliminate intentional diversions of spent pulping liquor, soap, and turpentine.

Some Tier II mills might need to increase the capacity of evaporators, recovery boilers, or recausticizing departments to accommodate the increased recovery of weak black liquor and the increased demand for white liquor associated with two-stage oxygen delignification.

As discussed in Section 3.2.2, to comply with the flow criteria for Tier II, extensive reuse of the condensates would be required. Reuse of condensates necessitates new or modernized evaporators because older evaporators generally allow small quantities of black liquor to carry over to the condensate, which can prevent the condensate being used for washing bleached pulp. The most recent evaporator systems produce very clean condensate, through use of integral steam strippers, that can be used for various purposes in the mill, and are also more energy efficient than older evaporators.

The two-stage oxygen delignification system for softwood lines would achieve a 65 percent reduction in incoming kappa number, which is the most efficient level of oxygen delignification currently known to be operating. High-efficiency oxygen delignification minimizes kappa into bleaching, thus minimizing the bleaching chemicals needed to achieve adequate brightness, and further reducing the potential for forming chlorinated organics, including dioxin and furan. Some of the more advanced oxygen delignification systems currently operating (e.g., Metsa Rauma in Finland (31)) use interstage washing; EPA assumes most mills upgrading their fiber line to achieve Tier II performance will operate using this approach.

Using the foregoing mill configuration, a high brightness softwood pulp with traditional five-stage bleaching would use the following sequence to comply with the Tier II limits: $O_wODE_{op}DED$. The E_{op} stage would probably be pressurized to increase the bleaching accomplished in this stage. As a result, the kappa factor could be low to minimize AOX formation. For the many mills currently operating a short bleach sequence (C/DE_oD or similar), the sequence $O_wODE_{op}D$ could be used to comply with the Tier II limits. A schematic diagram of a fiber line with this three-stage bleaching configuration is provided in Figure 3-6. This three-stage sequence was used as the basis to estimate costs, pollutant load reductions, and non-water quality environmental impacts of a Tier II - ECF configuration.

Tier II - Toward TCF Configuration

An alternative technical approach to the ECF process discussed above would be to select an ozone-based process design that could lead eventually to TCF bleaching, at minimal cost, while avoiding retirement of bleaching equipment before the end of its useful life. A bleaching sequence such as $O_wOZE_oD_nD$ could be used. Where the mill has only one chlorine dioxide stage for brightening pulp, the sequence O_wOZE_oD would be used, which is depicted in Figure 3-7. This latter sequence was used as the basis to estimate costs, pollutant load reductions, and non-water quality environmental impacts of a Tier II - Toward TCF configuration. This approach could also be operated in TCF mode, using a sequence such as O_wOZE_oPP.

The Tier II - Toward TCF configuration would have the same elements described above for the Tier II - ECF configuration, with the following modifications:

- Use of ozone in place of chlorine and/or chlorine dioxide in first-stage bleaching;
- Oxygen-enhanced extraction (Eo); and
- Improved water reuse within the bleach plant, including recycle of Eo stage filtrate to the post-oxygen washing.

The key difference from the ECF alternative discussed above is that an ozone bleaching stage is included. Use of ozone reduces the kappa number of the pulp prior to brightening with chlorine dioxide to well below the level normal with oxygen delignification. Typical kappa number target would be about 5. This would reduce even further the quantity of chlorine dioxide required, and also make it possible to recycle the ozone and extraction stage filtrates (amounting to about 50 percent of the bleach plant filtrate) to the recovery

Figure 3-6. Tier II – ECF Configuration

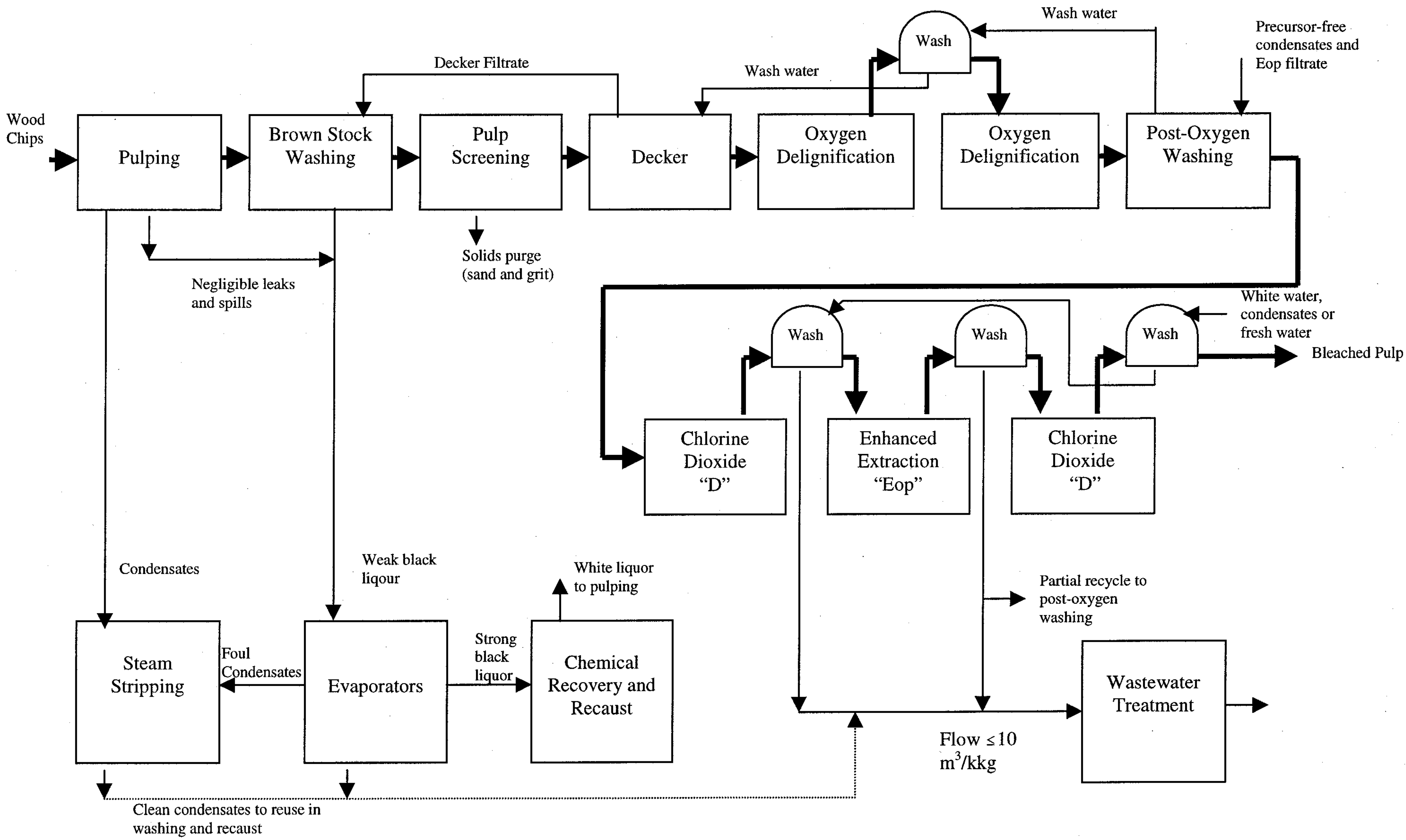
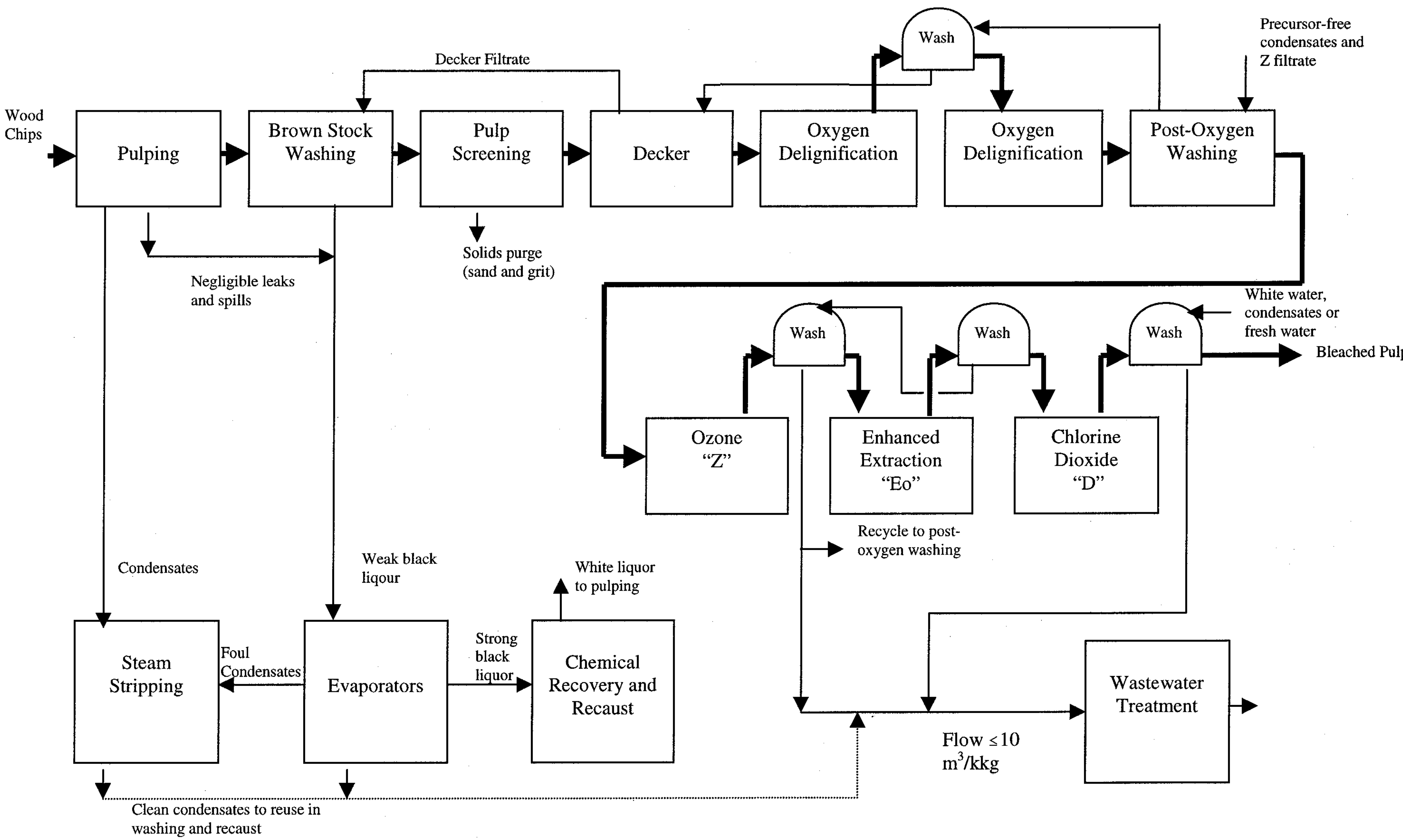


Figure 3-7. Tier II – Toward TCF Configuration



system without installing special equipment for removing chloride from the recovery cycle. In some cases, the use of ozone would avoid the need to increase the production of chlorine dioxide. Hydrogen peroxide could be used to reinforce the Eo stage, but this is not current practice in the best known mill in the U.S. that uses ozone [33]. Hydrogen peroxide has not been included in the technology basis because it is not needed to enhance the bleaching process, given the bleaching power of ozone. Mills that do not currently use hydrogen peroxide would not need to install hydrogen peroxide storage and handling facilities.

3.3 Tier III

3.3.1 Tier III Technology Basis

For Tier III, the ultimate performance requirement for AOX is a long-term average discharge of 0.05 kg/kkg or less, measured at the end of pipe. In addition, Tier III Advanced Technology fiber lines must recycle to chemical recovery systems all pulping-area effluent generated prior to bleaching that contain black liquor solids. Tier III mills must also meet limitations for dioxin, furan, chloroform, and the 12 chlorinated phenolic pollutants. The Tier III performance requirements reflect expected performance achievable with minimum impact techniques that are currently being developed. These technologies are not now completely defined, and additional technologies and innovations are expected to be developed over the next 15 to 16 years. No mill is currently meeting the Tier III performance requirements.

EPA expects that Tier III mills will have all of the technology elements described under Tier II. In addition, Tier III mills will likely recycle the majority of bleach plant filtrates back to the recovery cycle. To achieve the required degree of mill closure, the model Tier III mill will remove metals from bleach filtrate and chloride from the mill liquor cycle if chlorine dioxide is used for bleaching, and may perform more extensive steam stripping or other treatment of condensates than for Tier II to allow for full reuse. EPA also expects that Tier III mills will have advanced process control systems and negligible losses of black liquor. Finally, Tier III mills will likely have extended liquid storage capacity as part of their water recycle and liquor management systems to help maintain the hydraulic balance required for low discharge flow operation. It is anticipated that Tier III mills will capture and recycle - rather than discharge - liquors during fiber line disruptions through detailed planning of maintenance outages and contingency planning for unexpected disruptions.

3.3.2 Tier III Performance

3.3.2.1 AOX

EPA has established the AOX criterion for Tier III at 0.05 kg/kkg to reflect the performance projected to be achievable by mills using extended delignification and ECF bleaching technology, coupled with cutting-edge minimum effluent technology. As stated in the discussion of Tier II above, mills using TCF bleaching technology can achieve final effluent AOX values less than "ML."

ECF bleaching technology combined with significant bleach plant discharge flow reduction achieved through the recycle and reuse of bleach plant filtrates can have a significant impact on final effluent AOX load. Champion International is implementing its Bleach Filtrate Recycle (BFR™) process at its Canton, North Carolina mill. The BFR™ technology is operating on Canton's softwood $ODE_{op}D$ bleach line and the goal is to recycle the D_1 and E_{op} stage filtrates through brown stock washing and ultimately to the chemical recovery cycle. With the D_1 and E_{op} stages closed, Champion expects a 90 percent reduction in AOX from the softwood fiber line (16). When this reduction is applied to typical AOX discharge levels at mills with extended delignification and ECF bleaching (see Table 3-1), AOX in the range of 0.008 to 0.033 is expected to result.

The Alberta Pacific Forest Industries mill in Boyle, Alberta (AlPac) operates a swing line that pulps and bleaches hardwood 90 percent of the time, and softwood 10 percent of the time, using extend delignification and ECF bleaching technology. During the period January 1995 to May 1996, the final long-term average effluent AOX load for this mill was 0.056 kg/kkg [34]. The AOX data for this mill do not reflect the degree of flow reduction necessary to achieve pulping area and evaporator condensate and bleach plant flow rate of 5 m^3/kkg. As noted previously, flow reduction would contribute to further reduction in the total mass of chlorinated organic pollutants discharged.

A mill with an OZE_oD bleach sequence sampled by EPA discharged 11 m^3/kkg bleach plant filtrate containing 0.085 kg/kkg AOX [35]. Final treated effluent AOX data representing this bleach line are not available. However, assuming that a 45 percent reduction in AOX would be achievable by end-of-pipe treatment, a bleach line with this ECF technology would result in a final effluent AOX discharge under 0.05 kg/kkg. Also, further flow reduction to below 5 m^3/kkg would further reduce the discharge of chlorinated organic pollutants.

Based on these data, EPA has concluded that a long-term average AOX level of 0.05 kg/kkg reflects the performance of the Tier III technology basis. EPA promulgated an annual average limit equivalent to this long-term average, and is also promulgating a daily maximum limit based on this long-term average performance multiplied by an appropriate variability factor. The variability factors used were developed for BAT Option B. The Option B variability factor forms a rational basis for the Tier III variability factor because the core technologies that underlie both Option B and Tier III are extended delignification and ECF bleaching. As described above for Tier II, it could be argued that since the Tier III limits are lower than the Option B limits, variability under Tier III may be greater than under Option B. However, any such effect likely would be offset by the better process control strategies utilized by mills employing Tier III level technology. Therefore, EPA is using the Option B variability factor to represent the expected AOX variability under Tier III. Annual average limits, daily maximum limits, and the 1-day maximum variability factor are presented in Table 3-5.

Table 3-5

Tier III AOX Limits and Performance Levels for ECF Fiber Lines

Option	Long-term Average (Annual Average Limit) (kg/kkg)	1-day Variability Factor	Daily Maximum Limit (kg/kkg)
Tier III	0.05	2.28	0.11

3.3.2.2 Pulping Area Filtrate Recycle

Tier III includes a requirement to recycle pulping area effluents that contain black liquor solids, for the same reasons discussed in Section 3.1.2.3.

3.3.2.3 Discharge Flow

Under the Tier III BAT limitations, mills are required to maintain total pulping area condensate, evaporator system condensate, and bleach plant wastewater discharge flow of 5 m^3/kkg or less, reported as an annual average. Monitoring requirements are the same as stated above, under Tier II.

EPA has determined that best mills in the world that have implemented minimum effluent technology can achieve total discharge rates of bleach plant filtrate well under 10 m^3/kkg. These mills are listed in Table 3-4. Significant progress continues to be made in this area, and a few mills are heading toward total pulp mill closure. Several pulp and paper companies have stated that mill closure is a desirable environmental goal (2)[3637]

Metsa-Rauma's greenfield pulp mill, designed to use no chlorine chemicals in bleaching, began operations in March 1996. The goal of the mill's TCF process is a gradual closing of the mill's water cycles, resulting in a drastic reduction of mill effluents and water consumption. Currently the mill discharges 4 to 5 m^3/kkg bleach filtrate, with a total mill discharge of 12 m^3/kkg. In 1997, the Rauma mill plans to reduce total discharge to 10 m^3/kkg, with a future goal of 5 m^3/kkg. Clean and foul condensates from black liquor evaporation are collected separately. Foul condensates are purified by stripping, and then used (along with the clean condensates) for pulp washing, including bleached pulp washing (31).

Champion's Canton, North Carolina mill continues to work toward achieving a bleach plant flow below 5 m^3/kkg using its BFR™ process. Louisiana-Pacific expects to reduce discharge of its bleach plant effluent at the Samoa, California mill to about 2-3 m^3/kkg once it has optimized the bleach plant water balance and completed recausticizing area improvements to allow partial reuse of current Q stage discharges (5).

As described above, the mills leading the world in minimum effluent technology are reducing bleach plant filtrate discharges to under 5 m^3/kkg. In addition, some of these mills are reusing condensates to wash bleached pulp, and are developing other strategies to reuse pulping area and evaporator condensates when extensive bleach plant recycle is also practiced. Considering ongoing research efforts and progress made to date in reusing pulping area and evaporator condensates for bleached pulp washing and in other mill applications at minimum effluent mills, as described in Section 3.2.2.3, and in view of the 15-year development and implementation horizon for Tier III limits, EPA has determined that the appropriate Tier III flow limit is a combined discharge of 5 m^3/kkg or less of bleach plant filtrate and pulping area and evaporator system condensate.

3.3.3 Tier III Fiber Line Configurations

Both ECF and TCF technical approaches are possible to comply with the Tier III criteria. Both approaches are discussed below. The ECF approach is referred to in this document as the Tier III - ECF configuration, and similarly, the TCF approach is the Tier III - TCF configuration. Cost estimates, pollutant load reduction estimates, and non-water quality environmental impacts presented in Sections 5.0, 6.0, and 7.0, respectively, are based on a model mill converting to these configurations. However, in view of the substantial degree of mill process closure required, and the time allowed for compliance, it is likely that innovative technologies will be developed which would differ from the two alternatives discussed below.

Tier III - ECF Configuration

To comply with Tier III criteria, a mill which preferred ECF technology would probably have all of the elements described under Tier I, as well as the following characteristics:

- Recycle of virtually all bleach plant filtrates to the recovery cycle.
- System to remove metals from recycled bleach plant filtrates.
- System to remove potassium and chloride from the liquor cycle.
- An evaporator upgraded to segregate condensates, effectively, integral stripper, and carryover of black liquor solids below 5 ppm (expressed as Na).
- Best management practices to prevent or otherwise contain leaks and spills to the maximum extent feasible and eliminate intentional diversions of spent pulping liquor, soap, and turpentine. The BMP system would include extended storage capacity.
- Advanced process control systems.

The only commercial scale process for removing metals from recycled bleach plant filtrates and potassium and chloride from the liquor cycle is in operational trials at the Champion mill in Canton, NC [3839]. The Champion system is known as the "Bleach Filtrate Recycle™" (BFR™) process and incorporates a system to remove chlorides and potassium from the recovery boiler, a system to remove low-solubility metals from the acid filtrate from the bleach plant, and modifications to the bleach plant water system to minimize water input. The BFR™ process is mentioned frequently in this report because it is the most advanced system of its type operating in the U.S. Alternative processes exist, and several organizations (PAPRICAN, MoDo, Eka Chemicals) have active research and development programs which can be expected to result in further alternatives and competitors.

Within the BFR™ process, bleach plant filtrates are reused for pulp washing and ultimately recovered in the kraft recovery cycle. Chloride from bleaching a potassium from the wood are purged using a Chloride Removal Process (CRP), which operates on the basis of the greater solubility of sodium and potassium chloride relative to sodium sulfate. Electrostatic precipitator ash, which is enriched in chloride and potassium, is dissolved and recrystallized to produce solid sodium sulfate which is dissolved in black liquor and recovered in the recovery boiler, and an aqueous chloride and potassium waste stream discharged to wastewater treatment which acts as the purge of these substances from a BFR™ mill (17).

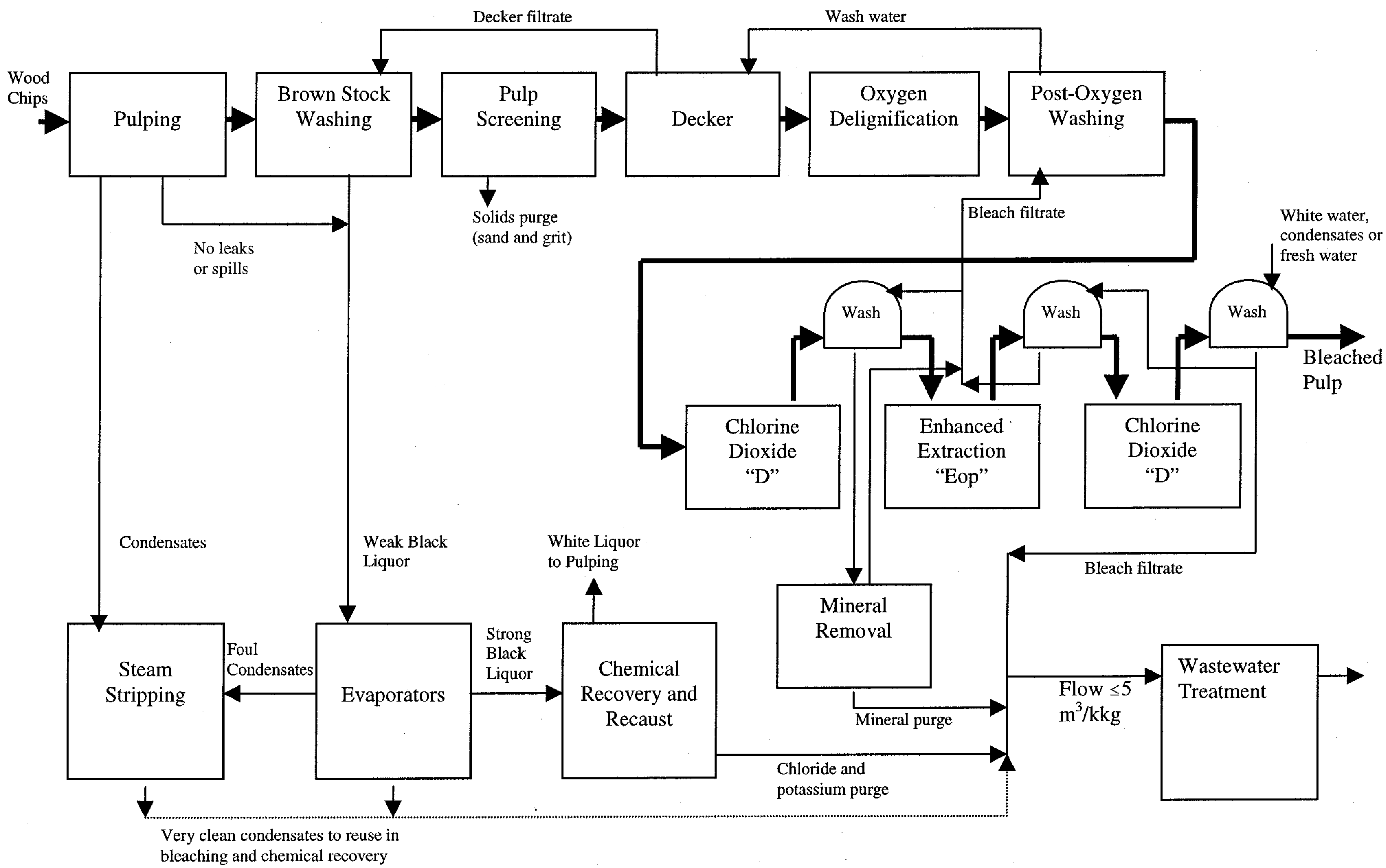
Mineral impurities from the wood such as calcium, magnesium, and manganese are purged from the system using a Metals Removal Process (MRP) to avoid the build-up of these substances and the subsequent adverse effects on mill operations. The MRP utilizes ion exchange to remove the minerals of concern from the first ClO_2 bleach stage filtrate, while exchanging them with an equivalent amount of sodium ions (17).

The BMP system would probably incorporate greater storage than for a normal mill to assist in maintaining hydraulic balance and to avoid discharges during transient upsets.

Well designed, modern process control systems, and a high quality of operator training would be necessary to attain sufficiently stable operation to comply with Tier III criteria.

It would be possible, but not necessary, to use an enhanced oxygen delignification system, as was the case under the Tier II - ECF configuration since the BFR™ system can remove the necessary amount of chlorides from a mill that has normal oxygen delignification, as demonstrated by operation at the Canton mill. A bleach sequence such as $ODE_{op}DED$ could be used. Where the mill has only one chlorine dioxide stage for brightening pulp, the sequence $ODE_{op}D$ would be used, which is depicted in Figure 3-8. The cost estimates, pollutant load reductions, and non-water quality environmental impacts of a Tier III - ECF configuration are based on this three-stage sequence, along with the other Tier III ECF technology components discussed above. Note that using the BFR™ technology does

Figure 3-8. Tier III – ECF Configuration



increase bleach chemical usage, including chlorine dioxide, since some pulp washing efficiency is lost due to the recycle of filtrates within the bleach plant.

Other ECF approaches may also be developed that the Tier III requirements that do not rely on BFR™ technology. For example, two-stage oxygen and ozone delignification could be used so only a small amount of chlorine dioxide would be used for final brightening. Such a mill could potentially recycle bleach plant filtrates and achieve Tier III requirements without the use of the chloride removal process. In addition, some mills are currently hoping to achieve the functional equivalent of MRP by installing an Ahstrom X-filter for green liquor filtration (5) so that metals will be removed from the process in filter dregs. EPA believes that these and other competitive technologies will evolve over the 16-year period mills have to comply with the Tier III requirements.

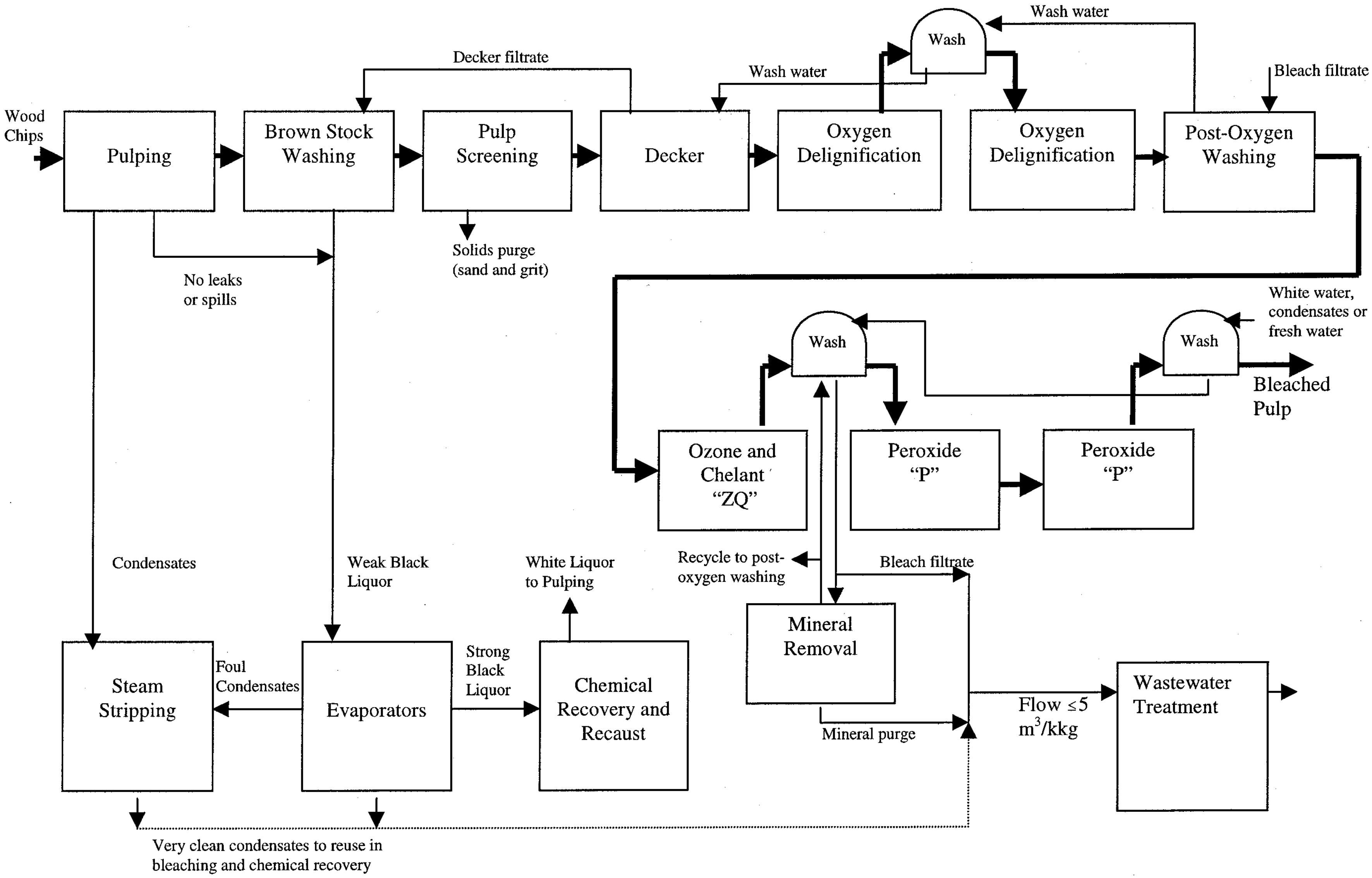
Tier III - TCF Configuration

A Tier III TCF mill would have all the characteristics discussed in Section 3.2.3 for a Tier II - Toward TCF Configuration as well as the following:

- Recycle of virtually all bleach plant filtrates to the recovery cycle;
- Equipment to remove metals from bleach filtrates;
- Hydrogen peroxide bleaching stage capable of using large charge effectively;
- Advanced process control system; and
- Extended storage for the BMP system.

EPA used the bleach sequence is OwO(ZQ)PP (depicted in Figure 3-9) as the model mill basis for the Tier III - TCF configuration cost estimates, pollutant load reduction estimates, and non-water quality environmental impacts presented in Sections 5.0, 6.0, and 7.0, respectively. This is only one of many possible TCF bleach sequences. Because much of existing mill equipment can be used to provide the necessary retention time and washing

Figure 3-9. Tier III – TCF Configuration



capacity for the peroxide brightening stages, bleach sequences are often determined by existing mill configurations.

To achieve bright, strong pulp while bleaching with peroxide, the kappa number of the pulp must be reduced to low levels prior to final brightening with hydrogen peroxide. This is achieved with the two-stage oxygen delignification followed by an ozone stage. Existing TCF mills have used a variety of approaches to achieve substantial brightness gains with hydrogen peroxide. These include raising temperature in existing towers, replacing an existing tower with a pressure vessel, and installing a short pressurized peroxide reactor immediately upstream of an existing bleaching tower. The model mill Tier III - TCF configuration is based on the latter technology.

EPA has noted that the two most modern TCF kraft mills in Europe have both observed serious problems with mineral scale formation when attempting to operate at effluent flows substantially below 10 m^3/kkg. Therefore, EPA's Tier III TCF model mill uses a system to remove calcium and related metals, similar to that used in the BFR™ process.

4.0 SCHEDULE TO IMPLEMENT ADVANCED TECHNOLOGIES

In order to promote the pollution prevention objectives of the Voluntary Advanced Technology Incentives Program, EPA has determined that existing mills choosing to participate in the program should receive a reasonable amount of time, beyond the time available for compliance with baseline BAT, to achieve the Advanced Tier performance levels they select.

The extended time frames discussed in this section are not available for new sources enrolled in the Voluntary Advanced Technology Incentives Program because the Clean Water Act requires new sources to comply with NSPS upon starting operation. However, new sources interested in participating in the Voluntary Advanced Technology Incentives Program after commencing operation may nevertheless do so, for example, by achieving the baseline NSPS requirements at the time discharges commence and later achieving the more stringent AOX and flow requirements of Tiers II or III. Once limitations equivalent to the selected advanced tier performance levels are placed in the mill's permit and the mill achieves those limits, it is eligible to receive incentives.

4.1 Schedule to Achieve Compliance with Tier Limits

EPA assumes that most mills, for practical purposes, will decide whether to participate in the Voluntary Advanced Technology Incentives Program within one year of the promulgation date in order to assure that they will have the maximum amount of time to achieve the various tier limitations.

EPA has determined that the following schedule by which existing sources can achieve Advanced Technology performance requirements is reasonable: 5 years for Tier I, 10 years for Tier II, and 15 years for Tier III. These periods are in addition to the initial year during which mills subject to Subpart B would decide whether to enroll in the Voluntary Advanced Technology Incentives Program. The 5-, 10-, and 15-year periods correspond to the time EPA believes a mill would need in order to arrange its financing and to develop, install, and test the chosen Advanced Technologies under Tiers I, II, and III, respectively. Support for the 5-, 10-, and 15-year periods is presented below.

4.1.1 Tier I

Five years is a reasonable time frame to achieve the Voluntary Advanced Technology BAT limitations corresponding to Tier I. The technology basis of the Tier I limits, extended delignification and 100 percent chlorine dioxide substitution for elemental chlorine, is commercially available, and can be designed, installed, and stabilized within the 5-year period. When spread over five years, the capital costs of the associated technologies become more affordable (although they are still significantly higher than the capital costs associated with the baseline BAT). The 5-year period makes the technology more affordable because it gives mills increased flexibility to schedule the significant capital investment within the mill's normal capital investment cycle (i.e., to purchase and install the necessary equipment when capital is available). Therefore, EPA believes the 5-year period will enable individual mills to participate in the Voluntary Advanced Technology Incentives Program that otherwise might not have the financial resources to make the necessary capital investment.

4.1.2 Tier II

Ten years is a reasonable time frame to achieve the Voluntary Advanced Technology BAT limitations corresponding to Tier II because the development and implementation of technologies to reduce bleach plant and condensate flow to 10 m^3/kkg pose technical and economic difficulties that EPA believes will take mills up to 10 years to resolve. (Once flow levels are reduced, EPA expects that mills also will be able to achieve the Tier II AOX limitations.) Recycling a substantial portion of pulping and evaporator condensates and bleach plant filtrates, with the attendant complexities of total mill water, chemical, and energy balances, requires considerable time before it can be implemented successfully at the mill scale. For example, when bleach plant filtrates are recycled, problems with scale and corrosion can take many months to over a year to develop and be observed. Once identified, fully correcting such problems can take significant additional time because of the time lag between action and observed effect in systems with high rates of recycle. In addition to problems with scale and corrosion, mills pursuing Tier II performance levels may have to solve challenges associated with reusing condensates, particularly if they must be used for bleached pulp washing. Consequently, EPA expects that Tier II mills will need to invest considerable time and effort to research and develop solutions to those technical problems. In addition to the technical challenges, significant capital costs can be involved in achieving Tier II limits, notably as a result of rebuilding or replacing full pulping and bleaching lines and upgrading associated evaporator equipment. Providing an extended time frame that allows a mill to make such capital expenditures on a schedule consistent with its planned investment cycle can make such large investments economically achievable. Examples supporting the 10-year compliance period for Tier II mills are provided below.

Champion, Canton, North Carolina

The Champion mill in Canton, North Carolina, currently approaching the Tier II flow and AOX levels, installed many of the relevant technologies in stages over what ultimately will be a 10-year period. The last three years of this installation period will be used for testing and fine-tuning the BFR™ reduced flow processes. Despite its significant progress in reducing bleach plant flows, even this mill still needs to address the technical challenges of further reducing condensate discharge flow before it would be fully able to achieve the Tier II BAT limits. The Canton mill needed 10 years to plan its multi-hundred million dollar renovation and pollution prevention investment, to arrange appropriate financing, to install supporting technologies at appropriate intervals and to research, develop, test, and refine its innovative flow-reducing processes. EPA believes that this mill's experience is representative of what other mills are likely to encounter as they work to achieve the Tier II limitations. [40]

Union Camp, Franklin, Virginia

The development of ozone delignification is another example supporting the 10-year period to develop, install, and make Tier II technology fully operational. Ozone delignification was studied extensively for about five years in the early 1970s by several companies, then development was abandoned due to a combination of technical difficulties in producing sufficiently pure ozone, lack of requirements to improve effluent quality, and lack of cost-competitiveness.

Union Camp began studying ozone in 1985, because they foresaw the possibility of using it to comply with local permit limitations. They searched the literature and conducted theoretical studies in 1985, and conducted laboratory studies throughout 1986 and 1987. They designed and built a pilot plant in their Eastover, South Carolina mill in 1987 to 1988, and started a pilot-plant operation in 1988. A new bleach plant (the “F-line”) was built at the company’s Franklin, Virginia mill in 1992. The F-line was designed and built to operate with or without ozone. After initial operating difficulties and further equipment development, the F-line was in full commercial production in late 1993, and has operated successfully since then. (33)

The total development time for bringing ozone delignification to full-scale commercial operation was therefore nine years from initial studies by the first successful developers. Other companies have also developed successful ozone delignification technology in the same time frame.

Louisiana-Pacific, Somoa, California

In September 1991, the U.S. Environmental Protection Agency, the Surfrider Foundation, and Louisiana-Pacific Corporation (L-P) agreed to terms of a settlement for L-P’s Samoa, California mill to meet more stringent wastewater discharge standards. L-P agreed to gradually convert the mill's bleached pulp production to 100 percent TCF pulp from September 1992 through September 1995, using an OQPPPP bleach sequence. TCF pulp was made in campaigns with a goal of gradually increasing duration as the market demand for TCF pulp increased. [41]

Process changes made at the mill in the 1980s paved the way for conversion to TCF bleaching and low-flow operation by the mid-1990s. Starting in 1986, pressure screens were installed and the brown stock screening area was closed. In 1989, an oxygen delignification system was installed. In 1990, a low-odor recovery boiler was installed, the evaporators were upgraded, and concentrators were installed. (41)

When operators had gained sufficient experience making TCF pulp (the pulp properties, particularly brightness, improved from campaign to campaign), the mill began research on ways to eliminate the bleach plant wastewater discharge. By May 1995, the mill had eliminated the wastewater discharge from all but the chelant stage. The mill was configured so that (eventually) half of the chelant stage discharge would be pumped to the recausticizing area for reuse and half would be used for upstream fiber washing. L-P installed a new green liquor filter in the recovery area in 1996 to accommodate this change. L-P also conducted a low-solids cooking trial in October 1995, which improved closed-cycle operation. Other improvements made during this same time included better process/hydraulic control. [42] Thus, in the course of 10 years, through a series of planned investments focused on creating a minimum-impact mill, L-P has installed most of the technology basis needed to achieve the Tier II limits.

Based on these experiences, EPA believes that the package of technologies underlying the Tier II Voluntary Advanced Technology BAT Limitations will be technically and economically achievable for mills aspiring to those performance levels within 10 years.

4.1.3 Tier III

Fifteen years is a reasonable time frame to achieve the Voluntary Advanced Technology BAT limitations corresponding to Tier III. As for Tier II, flow reduction again is the most difficult and time-consuming task. However, because reducing flow for pulping and evaporator condensates and bleach plant filtrates to 5 m^3/kkg or even lower approaches a closed mill configuration, even more technically difficult and time-consuming tasks must be successfully completed, necessitating five additional years beyond the Tier II time frame. For example, mills would probably need to install “kidney” technologies to remove metals and chlorides in order to control system scaling and corrosion problems while maintaining product quality and minimizing cross-media impacts. Successful completion of these tasks at individual mills will involve extensive research, process development, and mill trials. The types of corrosion and scaling problems EPA anticipates could take over a year of nearly closed-loop operation to identify and several more years of experimental modifications to mill operations to solve. Extensive time is required for such modifications because of the time lag in nearly closed mill systems from changing process conditions and observing the steady-state impact on hydraulic systems, liquor systems, and associated mill equipment. Mills may also need to embark on research, process development, and mill trials to achieve treated condensate quality that is sufficient to extensively reuse condensates. Mills will also need time to establish the complex mill water and energy balances necessary for nearly closed cycle operation. For these reasons, EPA believes that 15 years is a reasonable amount of time for a Tier III mill to perfect existing technologies or invent or develop new ones as necessary to achieve the Tier III performance levels.

4.2 <u>Interim Limitations</u>

The following interim limitations are applicable to existing sources as they make progress toward the ultimate incentives tiers limitations. As discussed in Section 4.0, new sources are eligible to enroll only at the Tier II or III levels and must achieve compliance with the associated performance requirements upon commencing discharge. Thus interim limitations are not applicable to new sources.

4.2.1 "Stage 1" Limitations

As described in the preamble for the promulgated regulations, EPA has established "stage 1" limitations for dioxin, furan, chloroform, AOX and 12 chlorinated phenolic pollutants that, for each pollutant, are equivalent to either the technology-based limit on that pollutant in the mill's last permit or the mill's current effluent quality with respect to the pollutant. These limitations are enforceable as soon as they are placed in the mill's permit.

EPA did not set "stage 1" limits at the baseline BAT level because the technology basis underlying the baseline BAT limits is not a logical first step to meeting the ultimate Advanced Technology BAT limitations. As a technical matter, mills subject to such interim limits most likely would need to install more chlorine dioxide generator capacity than they ultimately would use to achieve the Advanced Technology performance requirements. EPA believes most Advanced Technology mills ultimately will employ complete substitution of chlorine dioxide for elemental chlorine, preceded by extended delignification processes. Based on the current chemical application rates in the EPA Pulp and Paper BAT Baseline Database (14), EPA estimates the chlorine dioxide usage rates shown in Table 4-1 at mills using complete substitution of chlorine dioxide when differing degrees of extended delignification technology are also employed. As shown on the table, because extended delignification technology reduces the chlorine dioxide demand, immediate compliance with baseline BAT before mills have a chance to invest in extended delignification technology, could lead to installation of approximately 30 to 75 percent excess chlorine dioxide generation capacity.

Table 4-1

Reduction in Chloride Dioxide Usage Through Extended Delignification

Technology Basis	First D-Stage ClO2 Charge (kg/kkg pulp)	Brightening Stage ClO2 Charge (kg/kkg pulp)	Total ClO2 Charge	Percent Reduction over BAT Baseline
BAT Baseline	22	10	32	--
Tier I (oxygen delignification)	9-13, depending on percent delignification in OD	10	19-23	28-40
Tier II (Toward TCF Configuration)	eliminated	8	8	75

4.2.2 Interim Milestones

4.2.2.1 Limitations Equivalent to Baseline BAT

EPA is requiring mills at the Tier II and Tier III levels to achieve interim limitations equivalent to baseline BAT within six years. (Mills at the Tier I level must achieve, by year six, limitations equivalent to the baseline BAT requirements for dioxin, furan, chloroform and the 12 chlorinated phenolic pollutants as well as the ultimate Tier I performance requirements for AOX, kappa number, and filtrates recycling.) The interim milestones imposed on Tier II and III mills is a reasonable requirement because it reflects the technology performance Tier II and Tier III mills are likely to be achieving within this period. EPA expects that all Tier II or Tier III mills will need to install extended delignification and complete substitution (ECF) or TCF bleaching processes well in advance of achieving their wastewater flow objectives in order to allow sufficient time to design, install, test, and adjust their other flow reduction related processes. Thus, in EPA’s judgment, installation of extended delignification and ECF or TCF bleaching can and will occur within the first six years of the advanced technology program. Once these processes are installed, the mill will be achieving or exceeding the baseline BAT limitations.

Baseline BAT limitations also have been promulgated for AOX, measured at the end of pipe. The limitations are 0.623 kg/kkg on a monthly average basis, and 0.951 kg/kkg measured as a daily maximum. Comparing these limitations to the AOX performance levels of mills that have installed extended delignification technology, shown in Section 3.1.2.1, it is clear that mills will be able to achieve the BAT baseline limitations once they have installed extended delignification and ECF bleaching technologies.

4.2.2.2 Interim Milestones

A second set of enforceable interim milestones will be applied to all mills enrolled in the Voluntary Advanced Technology Incentives Program. The type and frequency of these milestones is left to the permit writer’s best professional judgment. As appropriate, milestones should include research schedules, construction schedules, mill trial schedules, or other milestones tailored to the circumstances and advanced technology at the participating mill. In addition to such schedule milestones, the milestones established at the Tier II and Tier III levels would likely include intermediate pollutant load and wastewater flow reductions.

In order to facilitate the development of appropriate interim milestones on a case-by-case basis, EPA is proposing a regulation that would require all mills enrolling in the incentives program to submit plans to their permitting authority detailing the strategy the mill will follow to develop and implement the technology they intend to implement to achieve the chosen incentive tier, and in the case of Tiers II and III, the interim numeric limitations. As proposed, these "Milestone Plans" would need to describe each envisioned new major technology component or process modification the mill intends to employ to achieve the Voluntary Advanced Technology BAT limits. A master schedule would need to be included in the plan showing the sequence of implementing the new technologies and process modifications and identifying critical path relationships within the sequence. For each individual technology or process modification, EPA proposes to require each enrolled mill to provide a schedule that lists the anticipated date that associated construction, installation, or process changes will be initiated, the anticipated date that those steps will be completed, and the anticipated date that the full Advanced Technology process or individual component will be fully demonstrated as operational.

For those technologies or process modifications that are not commercially available or demonstrated on a full-scale basis at the time the plan is developed, the plan would also need to include a schedule for research (if necessary), process development, and mill trials. As proposed, the schedule for research, process development, and mill trials would also need to show major milestone dates and the anticipated date the technology or process change will be available for mill implementation.

With respect to the level of detail required in the plans, EPA considers the individual major technology components and process modifications referenced above to be items such as:

- Oxygen delignification;
- 100 percent substitution of chlorine dioxide for chlorine;
- Closed screen room operation;
- Ozone delignification;
- Recycle of Eop filtrate to brown stock washers; and
- Reuse of clean condensate for bleached pulp washing.

The above list is not intended to be exhaustive, but rather is intended to provide through example the scope of the projects that would need to be specified in the milestone plan, if EPA promulgates the requirement as proposed. The Milestone Plan thus would need to include the following:

- Overview of Technical Strategy;
- Description of Technology Elements;
- Implementation Schedule
  - Master Schedule
  - Research and Development Schedule;
- Contingency Plans; and
- Appendix of Supporting Documentation.

The overview of the technical strategy would need to lay out the approach the mill intends to follow to achieve the ultimate limitation for the tier they are enrolling in. As proposed, the description of technology elements would need to provide a written description of each individual technology and process modification that the mill plans to employ. For technologies or process modifications not yet fully developed, concept-level descriptions would be sufficient.

EPA proposes to require mills to produce the schedules using common project management approaches, such as the Critical Path Method (CPM), the Program Evaluation and Review Technique (PERT), or equivalent methods. The primary attributes of these methods is that they show required project tasks, associated milestones, and interdependencies among tasks within the schedule. Enrolled mills would also be authorized to show project schedules using Gantt charts (bar charts) as long as the interdependencies among tasks are clearly defined.

As proposed, the plan also would need to address a process for consideration and concurrent development of appropriate alternative technologies or components as contingency in the event that initially identified technologies or components become problematic. These alternatives would be implemented, if necessary, at appropriate decision points in the master schedule to ensure that the ultimate tier limits are achieved by the dates specified in the permit.

Finally, if EPA promulgates the milestones plan requirement as proposed, the appendix of supporting documentation would need to contain sufficient information to validate the proposed technical strategy. Documentation such as vendor information, preliminary engineering studies, feasibility studies, research proposals or reports, and literature on minimum effluent and closed cycle technology may serve this purpose. EPA expects the permitting authority to use the information contained in these plans, as well as its own best professional judgment, to establish enforceable interim milestones applying all statutory factors.

5.0 COSTS OF ADVANCED TECHNOLOGIES

5.1 Cost Overview

Costs of complying with the Voluntary Advanced Technology Incentives Program BAT limitations and NSPS are presented in this section. The costs presented are based on two different scenarios:

- A base-case mill is upgraded to comply with the criteria of one of the BAT Incentives Tiers. This is described herein as a “modified” mill.
- A company decides to build a new fiber line. Such a fiber line might be a replacement of one or more fiber lines at an existing mill site, in which case the company could enroll the fiber line in BAT Incentives Tiers I, II, or III. In the alternative, the new fiber line might supplement existing fiber lines at a mill site, or be installed at a greenfield site, in which case the fiber line could be enrolled in either NSPS Incentives Tier II or Tier III. Whether complying with BAT or NSPS, the capital and operation and maintenance costs of an new fiber line would be the same.

In practice, it is possible for an intermediate situation to exist. For example, a company may be installing a new bleach plant, but intending to retain the existing digester and brown stock washing area. In this case, the costs of complying with one of the more advanced criteria would be between the two extreme cases mentioned above. EPA prepared detailed cost estimates for making the modifications in the first case to a model mill. These estimates are presented in Section 5.2. EPA also prepared estimates of the cost of installing new fiber lines. These estimates are presented in Section 5.3.

EPA estimated the costs of using both ECF bleaching and TCF bleaching wherever appropriate. Where new fiber lines are considered, TCF bleaching is slightly less costly than ECF bleaching. The differences in capital and operating costs are small relative to the total cost, and probably are less significant than the differences caused by site-specific conditions and by the quality of engineering and project management. In the case where an existing fiber line is to be retrofitted to comply with the Incentives criteria, TCF bleaching is generally substantially more expensive than ECF bleaching.

EPA estimated the costs presented in this section using a modified version of the BAT Cost Model [43]. The modified model is known as the "Incentives Program Cost Model." It uses the same equations and base data as the BAT Cost Model, with additional equations for the equipment and systems not included in the BAT model such as Bleach Filtrate Recycle (BFR™) technology and TCF bleaching equipment. These equations were developed on the same basis as the BAT equations, but in view of the limited number of BFR™ and TCF installations, they are not supported by the broad base of data that supports the BAT cost model equations.

5.2 Modifying a Typical Mill to Comply with Tier Limitations

5.2.1 Costs of Retrofitting a Case Study Mill to Comply with Tier Limitations

The capital and operating costs of converting a model mill to comply with limitations under the Voluntary Advanced Technology Incentives Program are shown in Table 5-1. The baseline BAT compliance costs for this model mill are also shown for comparison purposes.

As shown on the table, EPA estimated the costs for using ECF bleaching technology for all three tiers, and also for using a "Toward TCF" approach for Tier II and a full TCF approach for Tier III. The detailed technology bases underlying these cost estimates are described in Section 3.0 of this report. The annualized costs presented on the table were calculated in the same manner described in Section 10.2.4 of the Supplemental Technical Development Document (STDD) [44]. The costs per ton of pulp in Table 5-1 cannot be compared directly with those for a new fiber line, since the latter include costs for replacement of the whole fiber line.

Table 5-1

Costs of Compliance with Incentives Program Limitations for Case Study Mill

Technology Approach	Baseline BAT	Tier I - ECF	Tier II - ECF	Tier II - Toward TCF	Tier III - ECF	Tier III - TCF
Capital Cost	$18,515,000	$44,081,000	$51,652,000	$87,958,000	$70,866,000	$107,588,000
Additional Annual O&M Costs	$3,335,000	$876,000	($682,000)	$256,000	$134,000	$2,649,000
Annualized Cost[1], $/ton Pulp	$11.50	$13.40	$12.40	$23.90	$19.10	$33.80

Costs based on 1,000 kkg/day fiber line.

[1]Cost annualized using methodology described in Section 10.2.4 of the Supplemental Technical Development Document (44).

These costs represent the probable maximum for a mill to comply with the limitations established under the Voluntary Advanced Technology Incentives Program. They involve replacement of much of the existing bleach plant. In many cases, mills would be combining the modifications for the Incentives Tiers with modernization for other reasons, such as the end of useful life of existing equipment, so the real costs would be somewhat less.

There are differing opinions as to whether ECF or TCF technology is more appropriate for reducing effluent discharges to the levels required by the limitations for Tiers II and III. The cost for both ECF and TCF technology have therefore been estimated for Tier III. For Tier II, costs were estimated for an ECF approach and for a "toward TCF" approach, which would be a logical prelude to converting the mill to TCF operation, and would therefore be likely to be selected by mills with the intention of adopting TCF bleaching. Details are discussed below.

5.2.2 Model Mill and Base-Case Cost Estimates

EPA estimated costs for modifying one operating case study mill, from the technology level as it existed in late 1995 to the technology level of each of the incentives tiers. The case study mill is an integrated, 1,000 UBt/day, bleached kraft mill, with conventional pulping of softwood and hardwood on two lines of equal size. The mill currently bleaches with limited chlorine dioxide substitution using a three-stage C/DE$_{op}$D bleach sequence on each line. This is typical of the mills which are likely candidates for being upgraded to obtain the benefits available to mills complying with the criteria of the Voluntary Advanced Technology Incentives Program, as EPA assumes mills enrolling fiber lines in the Incentives Program at the Tier II and Tier III level will most likely be those in need of renovating or expanding large portions of the pulp mill (e.g., evaporators and recovery boilers). Modern, efficient equipment will greatly facilitate meeting the performance levels of the incentives tiers. The costs for upgrading to each of Tiers I, II, and III were estimated on the assumption that each of the fiber lines at the base-case mill would be modified for the same selected Tier in one cohesive modernization program, which may be spread over several years. The costs discussed herein therefore provide a comparison of the cost for upgrading to each tier, but do not provide any indication of the cost of converting fiber lines already complying with Tier II criteria to comply with Tier III criteria.

The baseline BAT cost estimate shown in Table 5-1 for comparison purposes is the cost for this mill to comply with the promulgated baseline BAT limitations, based on 100 percent substitution of chlorine dioxide for chlorine and the other elements of BAT Option A, described in the preamble.

5.2.3 Tier I Cost Estimate

The mill configuration that served as the basis of the Tier I cost estimate is fully defined in Section 3.1.3. The configuration includes oxygen delignification followed by ECF bleaching and is equivalent to BAT Option B.

5.2.4 Tier II Cost Estimate

EPA based the Tier II model mill cost estimates on two potential approaches. The first relies on two-stage oxygen delignification and 100 percent chlorine dioxide substitution for chlorine and is referred to as the Tier II - ECF configuration. The second is based on two-stage oxygen delignification and ozone bleaching, with some chlorine dioxide used for final brightening. A mill using this approach could ultimately convert to TCF operation by using peroxide for final brightening. This is referred to as the Tier II - Toward TCF configuration. The technology basis of these two approaches are fully defined in Section 3.2.3.

There is no specific cost allowance for the improvements in BMPs over Tier I that would be necessary for Tier II, because it is believed that the improvements will be realized primarily by improved operating skill. The cost model does include an allowance of 0.5 percent of the capital cost of all new equipment installations added to the annual operating cost, to allow for the increased level of technical support that is necessary when more advanced equipment is installed.

EPA assumed for the purposes of estimating Tier II compliance costs that mills already have condensate strippers, or will install them to comply with MACT or other regulations.

Some of the more advanced oxygen delignification systems currently operating (e.g. Metsa Rauma in Finland (31)) use interstage washing, and the costs for two-stage oxygen delignification estimated for the Tier II - ECF configuration is based on the assumption that this equipment would be included.

5.2.5 Tier III Cost Estimate

EPA developed cost estimates for both a Tier III - ECF configuration and a Tier III - TCF configuration. Detailed technology bases of these two approaches are provided in Section 3.3.3. In addition to the technology bases described in Section 3.3.3, EPA made the following technical assumptions in developing the Tier III cost estimates.

The BMP system would probably incorporate greater storage than for a normal mill to assist in maintaining hydraulic balance, and to avoid excessive discharges during transient upsets or maintenance outages and disruptions. An allowance for storing 10 m^3 waste waters per daily ton pulp production capacity in an outdoor pond is included in the capital cost estimate. (This is approximately five times the size of the storage assumed for calculating costs for BMP as part of the BAT cost estimates (43).

There is an allowance for the capital cost of the BMP system for Tier III of 50 percent greater than that for Tiers I and II, since it will have to be very efficient. There is no specific allowance for the improvements in operation of the BMP system over Tier I that would be necessary for Tier III, for the reasons discussed above for Tier II mills.

Well designed, modern process control systems, with rigorous statistical process control, and a commensurate level of operator training would be necessary to attain sufficiently stable operation to comply with Tier III limitations. An allowance for upgrading process controls has been included in the capital cost estimates.

EPA has noted that the two most modern TCF kraft mills in Europe have both observed serious problems with mineral scale formation when attempting to operate at effluent flows substantially below 10 m^3/kkg. The estimated costs for a system to remove calcium and related metals, similar to that used in the BFR™ process, are included in the estimate for complying with Tier III criteria, whether ECF or TCF.

5.3 Building a New Fiber Line to Comply with Tier Limitations

The foregoing discussion refers to retrofitting advanced ECF and TCF technology to an existing mill. Where a company is replacing an entire fiber line, or building a new fiber line, the capital costs differ substantially from retrofitting, and are discussed below. As discussed in detail in the preamble to the promulgated regulation, EPA is characterizing the replacement of entire fiber lines as an existing source modification if those fiber lines are enrolled in the Voluntary Advanced Technology Incentives Program, subject to BAT. Without enrolling in the Incentives Program, a fiber line replacement would be considered a "new source" subject to NSPS. A new fiber line, built either at a greenfield location or as a supplement to an existing fiber line, is a new source subject to NSPS, regardless of whether the new line is enrolled in the Voluntary Advanced Technology Incentives Program. However, such new fiber lines are eligible to enroll in the Voluntary Advanced Technology Incentives Program at either the NSPS Tier II or Tier III levels.

A company may decide to replace a fiber line for a number of reasons, typically a combination of the following:

- Increase capacity, while simultaneously shutting down one or more old systems;
- Reduce costs of labor, chemicals, repairs and energy;

- Comply with environmental or safety regulations; and
- Improve product quality.

Because it is easier to achieve the minimal effluent discharges that are required to comply with Tier III limitations in a new installation than when retrofitting an old one, companies are most likely to attempt to comply with the Tier III limitations on new (not retrofitted) fiber lines.

5.3.1 Baseline NSPS

EPA estimated the costs of two fiber lines capable of meeting the Baseline NSPS limitations. They are presented here for comparison purposes, and because they formed the basis from which NSPS Tier III costs were estimated. The first is based on ECF bleaching, and this technology is equivalent to Option B described in Section 3.1.3. The second is based on TCF bleaching, with a sequence based on one of the first greenfield TCF bleach lines in the world, commissioned in Ostrand, Sweden in 1996. Refer to Bodien [45] for a more detailed discussion of this mill. The estimated capital costs to install these two fiber lines are shown in Table 5-2. Operating cost impacts are shown in Table 5-3. For both technology bases, the change in operating costs for chemicals and energy relative to a new ECF fiberline with traditional pulping technology is also shown. Other operating costs (pulp mill, fixed costs, pulping makeup chemicals, wood, labor, and management) would essentially be identical to a new fiber line with traditional pulping and bleaching.

Although baseline NSPS limitations are not based on TCF technology, some companies might construct a greenfield TCF line. As shown on Tables 5-2 and 5-3, the estimated capital cost of the TCF alternative is slightly less than the ECF alternative, and depending on the cost of hydrogen peroxide, the operating cost could be similar.

Table 5-2

Capital Costs for Baseline NSPS

Configuration Name	Baseline NSPS	
	Entire ECF Fiber Line, Using OD	**Entire TCF Fiber Line**
New bleaching sequence	$OODE_{op}D$	OO (Q_w) (OP) (ZQ) (PO)
Unbleached Pulp Mill		
New continuous digester	$53,000,000	$53,000,000
New brown stock washing line	$19,400,000	$19,400,000
New closed screening system	$5,900,000	$5,900,000
Buildings and infrastructure	$6,000,000	$6,000,000
Subtotal, cost in pulp mill	**$84,400,000**	**$84,400,000**
Bleach Plant		
Oxygen delignification	$29,400,000	$29,400,000
New D-stage tower and washer	$15,500,000	—
New E_{op} stage, with washer	$11,300,000	—
New D-stage tower and washer	$15,500,000	—
New E2 stage with washer	—	—
New D-stage tower and washer	—	—
Chelant stage with press washer	—	$4,800,000
Pressurized PO stage with washer	—	$9,500,000
Capital cost of HC ozone system	—	$25,700,000
Pressurized PO stage with washer	—	$9,500,000
Chelant supply system	—	$200,000
Peroxide unloading and storage	$125,000	$125,000
Monitor bleach filtrates as effluent guidelines	$124,000	—
Buildings	$10,500,000	$6,000,000
Miscellaneous infrastructure	$14,400,000	$15,900,000
Subtotal, cost of bleach plant	**$96,900,000**	**$101,000,000**
Modifications Outside Fiber Line		
Greenfield chlorine dioxide plant	$16,200,000	$0
ClO_2 storage	$1,100,000	$0
Upgrade recausticizing	$3,100,000	$4,600,000
Total Capital Cost	**$202,000,000**	**$190,000,000**

Capital costs refer to complete installed cost.
Costs are based on a 1,000 kkg/day fiber line.

Table 5-3

Operating Costs for Baseline NSPS

Operating Cost Element	Baseline NSPS	
	Entire ECF Fiber Line, Using OD ($/kkg pulp)	**Entire TCF Fiber Line ($/kkg pulp)**
Cost (Saving) for bleach chemicals, relative to traditional pulping technology	($13.36)	($14.97)
Cost of additional on-site power demand relative to traditional pulping technology	$1.97	$7.68
Increase (reduction) in operating cost, relative to traditional pulping technology	($11.39)	($7.29)

Costs are based on a 1,000 kkg/day fiber line.

The comparative cost relationship between ECF and TCF technology installed in a new line, shown in Tables 5-2 and 5-3, is substantially different than when ECF and TCF technology are retrofitted in an existing line, as shown in Table 5-1.

The reasons for this substantial difference are:

- A new TCF facility would avoid costs for installing a plant to manufacture chlorine dioxide on site, whereas an existing mill would have already spent this money. The capital cost of a greenfield chlorine dioxide manufacturing plant for a 1,000 kkg/day bleached kraft mill typically costs approximately $25 million.

- TCF bleach plants are physically more compact than traditional ones, so a new TCF system requires less extensive buildings. An ECF or other older plant being retrofitted has, of course, already spent the money on buildings.

- TCF bleaching equipment can be built mostly of normal grades of stainless steels (typically ANSI 316 or similar), while ECF equipment must be manufactured with more expensive alloys and plastics to resist the corrosive action of chlorine dioxide and its degradation products formed in the bleaching process.

5.3.2 Tier III

A new Tier III fiber line would be different than baseline NSPS, because it would have to reduce long-term average AOX discharges to 0.05 kg/kkg or below, and bleach plant filtrates and pulping area and evaporator system condensates to 5 m^3/kkg or below. To implement the Tier III technology basis, a mill installing a new fiber line would need upgrades to the black liquor evaporators to ensure that the condensate was sufficiently clean to be used for washing the bleached pulp, upgrades to the recovery boiler to increase capacity to burn recovered bleach plant wastes, and a system to remove minerals from recycled bleach plant effluent to prevent scale build-up in process equipment. In addition, the ECF fiber lines would require a system to remove chlorides for the liquor cycle, and would thus be using the complete BFR™ process, or a competitive system with comparable performance. The TCF fiber line would not require a chloride removal system (the CRP component of BFR™) to be able to comply with the effluent flow criteria of Tier III, as chlorides are not introduced in the bleaching process. The total capital cost of including these facilities is shown in Table 5-4. The change in operating costs and annualized costs for these Tier III fiber lines, relative to a ECF fiber line with traditional pulping, is also presented in Table 5-4. If installed at a greenfield site, or as part of a major facility expansion, as would be the case under NSPS, considerable new evaporator and recovery boiler capacity would be provided and upgrades to existing systems would not be necessary.

In a situation where a new fiber line is being replaced due to obsolescence, or a completely new one is being constructed to increase mill capacity, it would be less expensive to build and operate a TCF fiber line with oxygen delignification that would comply with Tier III criteria than an ECF fiber line built to comply with Tier III criteria. The TCF bleach plants are somewhat simpler than ECF plants, and physically substantially smaller. In addition, the TCF chemicals are generally less corrosive than chlorine dioxide, so less expensive materials of construction can be used.

NSPS Tier II capital and operating costs were not estimated. They would fall between the baseline NSPS and NSPS Tier III costs presented in this section.

Table 5-4

Capital and Annual Costs for Equipping New Fiber Lines for Tier III Compliance

Configuration Name	Entire ECF Fiber Line, Using OD Tier III - ECF	Entire TCF Fiber Line Tier III - TCF
Capital Costs		
Cost without Tier III capability, From Table 5-2	$201,582,000	$190,285,000
Additional equipment for Tier III		
Modify evaporator for clean condensate	$2,147,206	$2,147,206
MRP component of BFR™	$12,207,926	$12,207,926
CRP component of BFR™	$12,081,341	---
Recovery boiler air system upgrade	$1,655,509	$1,655,509
Capital cost, with Tier III compliance	**$229,674,000**	**$206,296,000**
Change in Annual Costs Relative to Traditional Pulping Technology ($/t pulp)		
Cost (saving) for bleach chemicals	($13.36)	($14.97)
Cost of on-site power demand	$1.97	$7.68
Cost (saving) for operating metal and chloride removal technology	($1.00)	($4.00)
Cost (saving) for maintenance and technical support	($0.41)	($2.08)
Total increase (reduction) in operating and maintenance cost	($12.80)	($13.37)
Total increase (reduction) in annualized cost[1]	($10.86)	($17.84)

Capital costs refer to complete installed cost (total rounded to '000).
Costs are based on a 1,000 UBADt/day fiber line.

[1]Cost annualized using methodology described in Section 10.2.4 of the Supplemental Technical Development Document (44). Includes cost of capital.

6.0 POLLUTANT LOAD REDUCTION ESTIMATES

EPA performed a case study analysis to determine the potential effluent reduction benefits derived from the incentives program. Effluent reductions were calculated for a case study mill complying with Voluntary Advanced Technology BAT limitations at each incentive tier. The 1,000 metric ton per day case-study mill operates softwood and hardwood bleach lines of equal size, and, before modifications to meet the tier limitations, uses a conventional three-stage bleach sequence with chlorine on each line. Additional characteristics of the case study mill are provided in Section 5.2.2. The current estimated discharge load and effluent load reductions for each incentive tier are provided in Table 6-1. Effluent load reductions for baseline BAT are also presented for comparative purposes. The estimates were prepared assuming that the case study mill will use ECF-based bleaching technology at each of the tier levels. If TCF technology were used, there would be no generation of chlorinated pollutants at any of the tier levels.

The load reductions in Table 6-1 are based on the long-term average performance levels shown in Table 6-2. The performance levels shown under baseline BAT and Tier I are the same as documented in the STDD (44). The one exception to this is the AOX level under Tier I, which is the Tier I long-term average discussed in Section 3.1.2.

The AOX levels for Tiers II and III are the required performance levels, as discussed in Sections 3.2.2 and 3.3.2, respectively.

The BOD loads under Tiers II and III are estimated based on the assumption that the untreated BOD loads at Tiers II and III will be 10 and 6 kg/kkg, respectively, and 89.3 percent of this BOD will be removed in an end-of-pipe biological treatment system. The BOD percent removal is based on the average BOD percent removal observed at bleached papergrade kraft and soda mills in the EPA pulp and paper industry questionnaire database [46].

Table 6-1

Effluent Load Reductions for 1,000 Metric Ton Per Day Case Study Mill

Pollutant	Units	Current Discharge	Baseline BAT Reduction	Tier I Reduction	Tier II-ECF Reduction	Tier III-ECF Reduction
AOX	kkg/yr	860	670	770	830	840
BOD	kkg/yr	1,100	290	440	720	870
COD	kkg/yr	22,000	6,000	11,000	13,000	18,000
Color	kkg/yr	38,000	2,000	15,000	30,000	34,000
Chloroform	kg/yr	410	290	290	290	290
TCDD & TCDF	g/yr	5.0	4.9	4.9	5.0	5.0
12 Chlorinated Phenolics	kkg/yr	1,200	1,000	1,100	1,200	1,200

Table 6-2

Treatment Performance Levels Used to Estimate Incentive Tier Pollutant Loads

Pollutant	Units	Baseline BAT	Tier I	Tier II	Tier III
AOX	kg/kkg	0.51	0.26	0.1	0.05
BOD	kg/kkg	(a)	(a)	1.07	0.64
COD	kg/kkg	38.2	25.5	20[b]	10[b]
Color	kg/kkg	84.5	53.4	20[b]	10[b]
Chloroform	kg/yr	0.0003	0.0003	0.0003	0.0003
TCDD	ppq	5 (ML/2)	5 (ML/2)	5 (ML/2)	5 (ML/2)
TCDF	ppq	11.3	11.3	5 (ML/2)	5 (ML/2)
12 Chlorinated Phenolics	ppb	ML/2	ML/2	ML/2	ML/2

(a) Calculated from reduction in black liquor solids to treatment estimated by BAT cost model.
(b) Assumed LTA based on limited data.
ML = Minimum level.

EPA has limited COD performance data from which it projected the achievable performance levels under Tiers II and III. First, EPA proposed a long-term average COD load of 25.5 kg/kkg, based on Option B/Tier I technology. (EPA has not promulgated COD limitations for the reasons set forth in the preamble.) EPA expects lower COD discharges under Tiers II and III, achieved through tighter BMPs, reuse of condensates, and recycle of bleach plant filtrates. EPA measured the end-of-pipe COD load at a mill that uses TCF bleaching technology and has most of the elements of Tier II technology in place, but has no end-of-pipe treatment system. The COD load at this mill was 35 kg/kkg (12). If this effluent was treated in a biological treatment system that achieved 50 percent reduction in COD, typical of bleached kraft mills, the COD discharge load would be under 20 kg/kkg. The Champion mill in Canton, North Carolina achieves COD discharges in the 14 to 18 kg/kkg range (46). This mill operates two bleach lines, a softwood line with oxygen delignification, 100 percent substitution and BFR™ technology, and a hardwood line with oxygen delignification and 100 percent substitution. On average, this mill is assumed to approximate what could be achieved by a mill using Tier II technology. Considering the foregoing, EPA assumed Tier II mills could achieve 20 kg/kkg COD discharge for the purpose of estimating pollutant load reductions.

The Rauma mill, which is approaching the Tier III technology level, achieves a COD discharge of 6 kg/kkg (31). Considering this, the projected level of 20 kg/kkg of Tier II, and the degree of additional filtrate recycle and water reuse that will occur at Tier III mills compared to Tier II mills, EPA assumed that Tier III mills would achieve 10 kg/kkg COD discharge for the purpose of estimating pollutant load reductions.

EPA has performed a detailed assessment of projected color discharges at the Champion mill in Canton, North Carolina. EPA estimates this mill will achieve color discharges of 18 to 22 kg/kkg once it has optimized the technology it has in place [47]. EPA also measured the end-of-pipe color load of a mill that uses TCF bleaching and has most of the elements of Tier II technology in place but has no end-of-pipe treatment system. The average color discharge of this mill was 16 kg/kkg (15). Biological treatment has only a minimal impact on color, so this result can also be considered to reflect the performance of mills with end-of-pipe treatment. Based on the foregoing, EPA assumed Tier II mills could achieve 20 kg/kkg color discharge for the purpose of estimating pollutant load reductions. Based on flow reduction requirements and the trend observed in COD data, EPA assumed Tier III mills could achieve 10 kg/kkg color discharge.

EPA assumed levels of chloroform in end-of-pipe discharges will remain unchanged going from Tier I to Tiers II and III once the air releases and degradation that occurs in end-of-pipe biological treatment is accounted for. While discharges of chloroform from the bleach plant may be reduced under the advanced tiers because there will be a real reduction in chlorine dioxide application rates, EPA does not have any data from which to estimate the degree of reduction likely.

TCDD, TCDF, and the 12 chlorinated phenolics will not be detected in the bleach plant effluent under all of the technology levels shown on Table 6-2. EPA calculated additional reductions in the mass load of these pollutants under the advanced tiers based on the reduction in discharge flow rates under the incentives program.

7.0 NON-WATER QUALITY ENVIRONMENTAL IMPACTS

EPA evaluated the non-water quality environmental impacts and changes in energy requirements associated with the incentives tiers. EPA found that the technologies that form the basis of the incentives tiers provide a significant degree of water conservation, particularly at Tiers II and III. EPA also expects lower secondary sludge generation rates at incentives tier mills with activated sludge treatment because of reduction in BOD loads associated with the Advanced Technologies. The technology basis of each of the Incentives Tiers will lead to overall decreases in energy consumption, primarily because of replacement of chlorine dioxide with oxygen-based delignification and bleaching chemicals. EPA expects a slight increase in air emissions (under 2 percent) due to increased recovery of black liquor that will occur under the Incentives Tiers. However, these emissions are offset by reductions in air pollution that derive from the reductions in overall energy consumption. Note that the technology basis of Tier I is the same as BAT Option B. The impacts associated with Option B are described fully in the Non-Water Quality Environmental Impacts section of the Supplemental Technical Development Document (referred to as STDD, Section 11, throughout this chapter) (44).

7.1 Wood Consumption

7.1.1 Tier I

The impact of Tier I technology on wood consumption is the same as that EPA estimated for BAT Option B and BMPs. EPA concluded that wood consumption would be reduced by up to 0.3 percent as a result of greater retention of useful fiber associated with the recovery of spills (BMPs) and improvements in washing and screening of pulp. EPA also concluded that the installation of oxygen delignification without changing pulping conditions would have no affect on process yield. See the more detailed discussions in the STDD, Section 11, and the Effect of Oxygen Delignification on Yield of the Bleached Kraft Pulp Manufacturing Process [48] for further information supporting these conclusions.

7.1.2 Tier II

A Tier II mill would benefit from the marginal increases in wood yield from closed screening and spill recovery discussed above, but probably to a somewhat greater extent because the technology, control systems, and operational practices in such a mill would need to be excellent to achieve the Tier II performance requirements.

The effect of an advanced oxygen delignification system achieving 65 percent reduction in kappa number on wood yield is not known. McDonough [49] suggests that when oxygen delignification is extended beyond 50 percent, there will be a noticeable loss of yield. However, he also points out that this can be mitigated by the addition of magnesium salts. The reports published on the Rauma mill (31)[50] and Kemijarvi mill [51] (both mills operate oxygen delignification systems at 65 percent kappa number reduction) have not mentioned a loss of yield due to oxygen delignification. Because these mills continue to operate at high levels of delignification, it appears that if any yield losses actually exist, they are minimal, or at least acceptable to the mill owner even though they operate in regions where wood costs are about double U.S. costs. Stora recently commissioned a new bleach plant at their Skoghall mill in Sweden which incorporates a two-stage oxygen delignification system that reduces the kappa number of the pulp from 30 to 10. (confidential personal communication) Their laboratory work showed that this system would improve yield slightly. Given the above information, the best assumption is that wood consumption in a Tier II mill would be equal to or slightly less than that of a typical existing mill.

7.1.3 Tier III

Similar to Tier II, closing up screening and further improved spill recovery beyond that practiced at a Tier II mill would provide marginal increases in wood yield at mills employing Tier III technology.

To achieve the very low AOX limit and effluent flows required by Tier III, mills may use advanced oxygen delignification, followed by bleaching with extremely low doses of chlorine dioxide. Many mills would use TCF bleaching.

There are conflicting claims about the effect on yield of delignifying pulp to very low levels with chlorine-free chemicals. There are credible claims by at least one mill (Louisiana-Pacific, Samoa, California) which has operated a retrofitted TCF bleach line for over two years that there is no effect on overall yield. Senior operating staff at the two new TCF systems in Scandinavia (SCA, Ostrand and Metsa Rauma, Rauma) have stated that they see no loss in yield in their oxygen/ozone/peroxide TCF bleaching systems relative to an ECF system when operating full scale. These two bleach plants are "second generation" TCF lines, and are the only bleached kraft TCF operations in the world that were designed for TCF operation from initial concept. SCA believes that, theoretically, there must be a loss of about 1 percent in yield, but cannot see such a loss at the mill level. They have commented that the dissolution of wood in the peroxide stages on a mill scale is less than in the laboratory. (Personal communication with Goran Annergren, SCA.) Bodien (45) commented that mill staff believe there was no change in yield when the mill converted from ECF to TCF operation in 1996. This information indicates mills using TCF technology have not experienced a measurable decrease in yield.

At least some of the mills attempting to comply with Tier III criteria will be new, or have a new fiber line on an existing mill site. Such installations will be able to benefit from the technology recently developed at Rauma and Ostrand, as well as future developments in technology. Other mills will comply with Tier III criteria without fully converting to TCF processes, thus allowing pulp producers the possibility of avoiding the extreme cooking conditions used by some TCF mills. Therefore, for the purposes of estimating non-water quality environmental impacts and calculating mill energy balances, EPA assumed that there would be no change in yield for a future mill complying with Tier III criteria.

7.2 Effluents and Solid Waste

Implementation of the Voluntary Advanced Technology Incentives Program will reduce effluent flow, as well as the load of organic substances and suspended solids discharged to mills' effluent treatment systems. The reductions in hydraulic flows resulting from the implementation of Tier I limitations will have only a modest effect on effluent flows. Tier II and Tier III incentives, however, would reduce market pulp mill effluent flow by up to 85 percent. Integrated mills, which make up most of the US industry, have substantial wastewater flows from their papermaking operations. Consequently, the changes in flow resulting from the incentives will reduce integrated mill flow by a maximum of about 50 percent.

The reduction in BOD and suspended solids discharges under the incentives tiers will be significant, as discussed below. The extent of reduction will be progressively greater for the more advanced pollution prevention technologies associated with the Voluntary Advanced Technology Incentives Program.

7.2.1 Effluent flows

In 1995, the average mill discharged approximately 95 m^3/kkg effluent. EPA estimated that baseline BAT would result in wastewater flow reductions from 10 to 50 m^3/kkg. The greater reductions would be realized in mills presently discharging the highest flows. BAT Option B/Tier I would result in an additional reduction of up to 15 m^3/kkg at mills with the highest effluent flows. See STDD, Section 11, for additional detail.

Average bleach plant effluent flows for mills with and without extended delignification are shown below.

Bleach Plant Effluent Flow for Mills with and without Extended Delignification

	Hardwood	Softwood
Mills without oxygen delignification or extended cooking	24.7 m^3/kkg	37.1 m^3/kkg
Mills with oxygen delignification or extended cooking	19.7 m^3/kkg	24.7 m^3/kkg

Source: DCN 13952, Record Section 24.

Condensates contribute an additional 10 m^3/kkg if they are discharged rather than reused. In the case of Tiers II and III, discharge flow of bleach plant filtrate and pulping area and evaporator condensates would be reduced from these levels to a total discharge of 10 m^3/kkg and 5 m^3/kkg, respectively.

7.2.2 Solid Wastes

EPA estimates that the implementation of all three incentives tiers would result in a significant reduction in the generation of sludge in effluent treatment systems. The reduction in sludge generation results from the decrease in organic load discharged to the effluent treatment system. Somewhat offsetting the decrease in wastewater treatment sludge, mills complying with Tier III criteria would generate small quantities of solid waste as they purge calcium and manganese salts from the recausticizing system if certain mineral removal equipment is installed. This material would be in the form of a sludge, rather than discharged in the wastewater effluent as is current practice.

7.2.2.1 Primary Sludge

BAT Option B/Tier I technology will result in reductions in primary sludge generation. As discussed in the STDD, Section 11, on average this will result in an 2 kg/kkg reduction in primary sludge generation, primarily due to the reduction in losses of useful fiber associated with recovery of spills and improved pulp washing and screening (see Section 7.1.1).

Primary sludge generation of Tier II and Tier III mills would be further reduced due to recycle of bleach plant filtrates. Bleach plant filtrates generally contain from 20 to 100 mg/L of fine fiber. This concentration is generally constant for any given mill, regardless of flow, because it depends on the size and type of openings in the washer wire or other filter medium. In a typical bleach plant discharging 40 m^3/kkg effluent, approximately 2 kg/kkg sludge might be formed due to the fiber losses. Compliance with Tier II or Tier III criteria would reduce this amount by about 90 percent. The exact reduction will depend on equipment selected for washing in the "low-effluent" bleach plant.

Approximately 3 kg/kkg additional fiber would be recovered by the overall mill optimization that would be necessary to comply with Tier II or Tier III criteria, and therefore would reduce the generation of primary sludge.

7.2.2.2 Secondary Sludge

As discussed in Section 11 of the STDD, BAT Option B/Tier I technology will result in a 3 percent reduction in secondary sludge generation due to a reduction in the BOD waste load to secondary treatment.

The effects of modifying mills to comply with Incentives Tiers II and III will be similar to those of Tier I, but greater in magnitude, because the mills will return greater quantities of organic material to the recovery process that would otherwise be discharged as BOD and be converted to sludge in mills' waste treatment plants.

Consideration of the processes likely to be used to comply with Tier II criteria indicates that the raw waste load of BOD discharged to the effluent treatment system would be about 10 kg/kkg pulp. Typical base case mills will discharge approximately 38 kg BOD/kkg pulp [52]. The 28 kg BOD/kkg pulp reduction in raw BOD will result in a reduction in solid waste formation in activated sludge treatment plants of approximately 17 kg/kkg pulp, assuming 0.6 kg of biological (secondary) sludge is generated in an activated sludge system for each kg of BOD applied [53]. Approximately one-third of mills use the activated sludge process (52), representing

23 percent of total bleached kraft subcategory production. The total bleached kraft production is 83,500 unbleached kkg/day, so the reduction in sludge formation relative to base case sludge production of 2.5 million tons/year is 112,000 tons/year (dry basis), or about 4 percent. Tier III limitations will have a similar effect, driving raw BOD discharges down to about 6 kg/kkg pulp, thus reducing the formation of secondary sludge by 126,000 tons/year relative to baseline (5 percent reduction). See the STDD, Section 11, for additional details supporting these calculations.

Approximately two-thirds of mills in the bleached papergrade kraft subcategory use aerated stabilization basins (ASBs), some in combination with activated sludge treatment (52). Though generating much less sludge than activated sludge treatment, ASBs often become partially filled with sludge after a number of years of operation, and require dredging. Lightly loaded ASBs have the ability to mineralize organic sludge, and may never require clean out. As discussed above, the incentives tiers will reduce the discharge of BOD and suspended solids to treatment and thus reduce ASB dredging frequencies.

7.2.2.3 Other Solid Waste Generation

EPA expects no increase in solid waste generation at Tier I or Tier II mills. Bleach plants at the L-P Samoa, SCA Ostrand, and Rauma mills already discharge under 10 m^3/kkg effluent and they have not experienced increased solid waste generation. In order to meet Tier II flow criteria, mills like these would need to reduce the discharge of evaporator and digester condensates, which could require additional stripping (to reduce TRS or methanol content) or cooling. Neither of these operations is likely to generate more solid waste than the present method of disposal or use.

As Tier III mills approach process closure, they will need to remove some nonprocess elements from the system as solids instead of discharging them as dissolved matter in the effluent, to prevent process equipment scaling. The dissolved matter is primarily calcium, manganese, and iron. The two most likely methods of disposal are by filtering these minerals from the green liquor (in which their solubility is low) in the recausticizing department, or by using a process such as the Metals Removal Process (MRP) described by Caron (17). There are several green liquor filters operating to remove minerals (50)[54]. These are cross-flow or "fabric-sock" filters that replace or supplant the conventional green liquor clarifier.

A full-scale MRP is currently being operated at the Champion mill in Canton, North Carolina (17). A high proportion of the metals entering the mill with wood or as impurities in purchased chemicals are washed from the pulp in the first acid stage in the bleach plant. The MRP removes metals from this stream. While the system at Champion is proprietary, the principle can be applied in several ways. Jaegel estimated that the total quantity of minerals to be removed from a completely closed (effluent-free) system would be 16 kg/kkg pulp (54). Since Tier III mills will not be completely closed but rather have some bleach plant discharge, the total quantity of minerals removed from a Tier III mill would be less, in the range of 10 to 15 kg/kkg.

In a conventional, relatively "open," kraft mill, nonprocess elements such as potassium and chloride are eliminated from the system by discharge in the mill's wastewater. Tran has shown that as mills approach process closure, the concentrations of chloride and potassium throughout the liquor system rise, which can cause plugging on the fireside surfaces of the chemical recovery boilers [55]. Thus, chloride and potassium need to be purged from the system to maintain efficient recovery boiler operation.

Potassium and chloride concentrate in the dust caught in the electrostatic precipitator of the kraft mill recovery boiler. This dust is normally returned to the liquor cycle. To control the concentrations of potassium and chloride in the mill's liquor cycle, Tier II and Tier III mills will have to remove and discharge potassium and chloride. This can be done by discharging a portion of the precipitator dust, which is a mixture of inorganic salts of sodium and potassium, or by using a specialized process designed for this purpose, such as CRP. See Section 3.3.3 for a description of CRP. Potassium and chloride discharged through these mechanisms would have been previously discharged at a traditional mill with the pulp mill and bleach plant effluents; the point of discharge from the cycle has simply moved. The benefit derived from the

Tier II and Tier III technology, however, is that the organic material that was also previously discharged is now burned in the recovery boiler.

The precipitator dust discharge, which may be up to 20 kg/kkg pulp, has been described as a solid waste discharge in some documents. However, in many mills the dust never exists in dry form except between the plates of the precipitator, and is normally discharged as a solution in the effluent[1].

In any event, EPA estimates that the quantity of chloride discharged from a Tier II or Tier III mill will be substantially less than is discharged from a traditional mill because of the reduction in use of chlorine-based bleaches, and the probability that mills wishing to operate within the incentives limitations will avoid purchasing chemicals contaminated with chlorides.

Most of the potassium in a mill system enters with the wood and purchased chemicals (55). The potassium entering with the wood will be discharged by any mill, whether operating like a pre-1970 mill, or in accordance with Tier III criteria. EPA estimates that the quantity of potassium entering with the chemicals, and hence being discharged, will be less in the more advanced mills, because the quantity of chemicals purchased will drop due to recycle as well as the mill operator's desire to avoid purchasing contaminated chemicals to minimize the problems caused by potassium in the mill.

7.3 Energy Impacts

7.3.1 Overview of the Energy Impacts

Sections 304(b) and 306 of the Clean Water Act specifically direct EPA to consider the energy requirements of effluent limitations guidelines and standards it establishes. EPA estimated the impacts of BAT Option B/Incentive Tier I on a mill-by-mill basis. These estimates are presented in Section 11 of the STDD. For Tiers II and III, EPA estimated the

[1]Quantities are small. The BFR™ process at Canton, North Carolina, which is the largest chloride removal system operating in the U.S., discharges approximately 30 m^3/day, or 0.03 percent of total mill discharge flow.

energy use associated with a typical model mill in the bleached papergrade kraft and soda subcategory. The energy impacts were calculated for the same model mill and associated base-case conditions used to prepare cost estimates, described in Section 5.0. For each tier, EPA analyzed the following changes in energy use:

- On-site electrical demand within the mill;
- Electrical demand for wastewater treatment;
- Steam demand for pulp cooking, bleaching, black liquor evaporation, etc.; and
- Off-site electrical demand resulting from manufacture of bleaching chemicals.

Table 7-1 presents EPA's estimate of the effect of the incentives tiers on energy consumption relative to base-case conditions, scaled to the entire Bleached Papergrade Kraft and Soda Subcategory production. Electrical and thermal energy are combined and converted to an "oil equivalent" in Table 7-1 to conveniently compare the total energy demand of each Tier. Assumptions used in the conversion to "oil equivalent" are presented in Section 7.3.3.

The energy savings associated with Tier II principally derive from replacement of chlorine dioxide by oxygen-based bleaching agents that require less energy to manufacture. There would be a further reduction in total energy consumption if Tier III was implemented throughout the industry, due again primarily to the replacement of chlorine dioxide with more energy-efficient bleaching chemicals.

Table 7-1

Effect of Incentives Tiers I, II, and III on Energy Consumption Relative to Base-Case Conditions

		Tier I (Option B)	Tier II - ECF	Tier II Toward TCF	Tier III - ECF	Tier III - TCF	Notes
Increase (decrease) in off-site power consumption	MW	(161)	(228)	(619)	(228)	(776)	a
Increase (decrease) in on-site power consumption	MW	66	139	577	127	527	
Total increase (decrease) in power consumption	MW	(95)	(89)	(43)	(101)	(249)	
Increase (decrease) in thermal energy to generate power	GJ/day	(32,800)	(21,136)	(21,136)	(4,405)	6,133	b
Total increase (decrease) in fuel consumed	bbl/yr	(1,540,000)	(3,020,000)	(2,090,000)	(2,290,000)	(4,660,000)	c
Increase (decrease) in fuel consumed relative to total energy consumption by bleached kraft subcategory in 1995		(2%)	(4%)	(3%)	(3%)	(6%)	c

[a]Off-site power consumption is for manufacture of bleaching chemicals.
[b]Estimate of thermal energy required assumes overall efficiency of condensing power station and distribution system of 25 percent.
[c]See DCN 14510 for baseline energy calculations of 116 million bbl/year.

Scaled to Full Bleached Papergrade Kraft and Soda Subcategory production.

7.3.2 Estimation of Energy Impacts

EPA evaluated the effect of each process change associated with complying with the incentives tiers on demand for steam and electrical energy. The process changes which have a significant effect are listed in Table 7-2. Items described as “insignificant” or “minor” were excluded from calculations of changes in energy consumption because they have no discernible impact within the accuracy of the estimate. In addition to the explicit process changes, EPA accounted for the consequential effects that reducing effluent flow and BOD load would have on energy consumption in the mills’ wastewater treatment plants (WWTP).

The actual process changes required, along with the actual quantities of steam and electricity involved are mill specific, and were calculated for the incentives model mill by the cost model. Details of the assumptions and associated equations for energy impacts are defined in the BAT Cost Model Support Document (43).

The manufacture of sodium chlorate for on-site chlorine dioxide generation is a major factor in offsite electrical energy demand. Production of chlorine dioxide requires approximately 11 kWh/kg, whereas the equivalent quantity of oxygen only about 1 kWh/kg. Thus, use of oxygen delignification to reduce chlorine dioxide demand results in net electrical energy savings off-site. In addition to reductions in chlorine dioxide use, all of the potential bleach plant modifications with the technology basis of the incentives tiers will reduce the demand for electrolytically produced caustic, and so will also reduce demand for off-site electrical energy. The difference in power required for the various alternative bleaching processes are calculated in the cost model, and are included in the results presented in Table 7-1.

7.3.2.1 Energy Impacts of Tier I

Tier I technology basis is identical to BAT Option B, so the averages of the mill-by-mill calculations for Option B, presented in Section 11 of the STDD, were used to represent the Tier I energy impacts, as shown in Table 7-1.

Table 7-2

Process Changes Affecting Energy Consumption

Process modification	Steam demand	Electrical demand
Improve brown stock washing and screen room closure	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor Reduced demand from reduction in water to evaporate	Minor, may be plus or minus
Extended cooking	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor	Insignificant in fiber line Net reduction in off-site power for bleach chemical manufacture
Oxygen delignification	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor Heat demand for oxygen reactor	Additional mixing energy in fiber line Net reduction in power for bleach chemical manufacture
High chlorine dioxide substitution	Minor increase	Increased energy for pulp mixing Increased energy off site for bleach chemical manufacture
Best Management Practices	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor Steam demand to evaporate recovered water	Insignificant
Evaporator upgrade	Steam demand increase	Insignificant
Evaporator load reduction	Steam demand decrease	Insignificant
Measures to compensate for increased load on recovery boiler:		
` Recovery boiler upgrade	Steam generated from above-mentioned black liquor replaces some steam from fossil fuel	Minor change
` Anthraquinone pulping additive	None	None
` Black liquor oxidation	Reduction in net demand since steam generated in reaction is used for evaporator	Increase
Recausticizing upgrade	Insignificant	Minor change
Reduction in effluent flow due to above	None	Minor reduction in pumping energy
Reduction in effluent BOD due to above	None	Reduction in WWTP power
Ozone delignification	None	Approximate 10 kWh/kg ozone Energy for mixing in fiberline
Peroxide stages, including E_{op}	Minor	Net decrease, due to replacing chlorine dioxide
Bleach filtrate recycle	Steam for evaporator/crystallizer	Minor

Table 7-2 (Continued)

Process modification	Steam demand	Electrical demand
Reduction in effluent flow due to above	None	Minor reduction in pumping energy
Reduction in effluent BOD due to above	None	Reduction in WWTP power

7.3.2.2 Energy Impacts of Tier II

Calculations of the energy impacts of Tier II and Tier III were based on the changes estimated for a 1,000 kkg/day fiber line extrapolated to the total U.S. bleached kraft production. The process elements that impact energy consumption at mills meeting Tier II or Tier III criteria are listed in Table 7-2.

The principal differences between a Tier II - ECF mill and a BAT Option B mill with respect to energy consumption are:

- The additional stage of oxygen delignification would require more electrical energy on site; and
- The lower prebleaching kappa number would reduce chlorine dioxide demand.

The net effect of implementing Tier II technology in a 1,000 kkg/day mill would therefore be to decrease total electrical power demand by 1 to 2 MW, depending on whether the mill chose the ECF or "Toward-TCF" process concept.

Bleached kraft pulp production in the U.S. is approximately 83,500 kkg/day, and the effect of applying Tier II technology to the whole industry relative to the base case, is shown in Table 7-1.

7.3.2.3 Energy impacts of Tier III

Two scenarios are considered for Tier III. The first (ECF) assumes that the mill would recycle bleach plant filtrates to the recovery system, and remove metals and chlorides by Champion's BFR™ or a competitive process. The second scenario (TCF) assumes that the mill would use ozone and peroxide to replace all of the chlorine dioxide, thus allowing recycle of most or all of the bleach plant filtrates to the mill's recovery system.

Tier III with ECF Bleaching

To comply with Tier III limitations while using ECF technology, a mill would likely have to return bleach filtrates to the recovery cycle (as in the BFR™), or concentrate and burn them separately as proposed by EKA Chemicals, H.A. Simons, Zerotech Inc., and others. The following discussion is based on the BFR™ process.

The principal differences between a Tier III mill using the BFR™ or similar process relative to BAT Option B with respect to energy consumption are:

- There is an additional steam requirement for the evaporator/crystallizer in the chloride removal system amounting to approximately 125 kg/kkg pulp, equivalent to 0.34 GJ/kkg (39).
- There is an additional power requirement of approximately 15 kWh/kkg pulp (39) for the pumps required for transporting the fluids in the BFR™ process.
- The organic waste recovered from the bleach plant would increase steam generation in the recovery boiler by the equivalent of 0.5 GJ/kkg pulp.

Bleached kraft pulp production in the U.S. is approximately 83,500 kkg/day, and the effect of applying Tier III - ECF technology to the whole industry relative to the base case is shown in Table 7-1.

Tier III with TCF Bleaching

The principal differences between a TCF Tier III mill and a BAT Option B mill with respect to energy consumption are:

- The more powerful oxygen delignification system and the Z and E_{op} stages would recover black liquor solids generating additional steam. This is due to recovery of most of the organic material removed in bleaching.

- The additional stage of oxygen delignification would require more electrical energy on site.
- The lower prebleaching kappa number would reduce chlorine dioxide demand to zero, avoiding the need to generate power off site to manufacture the sodium chlorate feedstock for the mill's chlorine dioxide generator.
- The replacement of chlorine dioxide with ozone would require approximately 100 kWh/kkg pulp, primarily for the ozone stage, including both on-site ozone generation and the mixing energy required for fiber processing. For the 1,000-kkg/day capacity model mill, this represents 4.2 MW.

The net effect of implementing Tier III technology in a 1,000-kkg/day mill would therefore be to decrease total electrical power demand by approximately 3.1 MW, and decrease the need to burn fossil fuel to raise steam for process heating at the mill by the equivalent of 77 GJ/day.

Where the pulp mill is integrated with paper mills, all the additional steam produced by the more efficient process would probably be used on site with consequent reduction in use of fossil fuel for steam generation. In the interests of maximum energy efficiency, the mill would cogenerate electrical power. In the case of a market kraft mill, there could be more electrical power available from burning the recovered organic material than would be required at the mill. One example is the Rauma mill (50)[56]. In such cases, the excess power would be sold, so that the above mentioned conservation of fossil fuel would appear at a remote electrical generating utility instead of at the mill site.

The effect of applying Tier III - TCF technology to the whole industry, relative to the base case, is shown in Table 7-1.

7.3.3 Equivalence of Various Forms of Energy

EPA calculated an “oil equivalent” to conveniently present the combined effects of the changes in thermal energy and electric power. The oil equivalent is based on the assumption that all nuclear, hydroelectric, waste fuel, natural gas, coal, cogeneration, and wind power systems across the country are operated at their maximum capacity, and that any increase or decrease in fuel electric power demand caused by the effluent guidelines regulations is supplied by conventional condensing-type oil-fired power stations. (If EPA assumed that additional electrical demand would be supplied by coal or natural gas burning facilities, then the predicted effect on fossil fuel consumption would be quite similar. It is expressed in terms of oil equivalents here for convenience of the reader. Coal equivalents could also reasonably be used.) For example, a mill burning all its black liquor and hog fuel would normally also burn some purchased fossil fuel (oil, coal, or natural gas) to raise steam. All the black liquor must be burned, but the mill cannot normally increase the quantity of black liquor generated, since it is directly related to the pulp production rate. The hog fuel is relatively inexpensive, so all available material will be burned at all times, subject to any limitations in wood burning equipment. Any change in the requirement for process steam will be supplied by changing the quantity of fossil fuel purchased and burned.

Many mills also generate some or all of the electric power they require by passing steam through turbines prior to using it as process heat. This power (known as cogenerated power) is relatively inexpensive, so mills normally operate their cogeneration equipment to its maximum potential. Some generate more power than is required on site, and sell the surplus to the local utility or other customer. Whether the mill is a net buyer or seller of power, any change in on-site power demand will be passed on to the national electrical power grid, reflecting ultimately in the load on utility stations.

The overall efficiency of conversion of thermal energy in fossil fuels to electricity delivered to consumers is approximately 25 percent. This is because thermal power stations ultimately reject approximately two-thirds of the thermal energy derived from combusted fuel due to the thermodynamic properties of steam. There are losses of energy to the stack gas, and mechanical and electrical losses in the turbines, generators, and distribution system. In addition, a small fraction of the power generated is used in the utility plant itself for motors, electrostatic precipitators, and other necessary auxiliary equipment.

To convert the steam demand calculated as metric tons per day to equivalent barrels of oil, EPA made the following assumptions: one ton of steam equivalent to 2.7 GJ and; steam plant operating at 75 percent efficiency; and one barrel of oil equivalent to 6 GJ.

7.4 Atmospheric Emissions

Sections 304(b) and 306 of the Clean Water Act specifically direct EPA to consider the air pollution impacts of effluent limitations guidelines and standards it establishes. EPA estimated the impacts of the Tiers I, II, and III on the generation and emission of air pollutants associated with a typical model mill in the Bleached Papergrade Kraft and Soda Subcategory. These options will affect atmospheric emissions in a number of ways.

` Pollution prevention and control technologies that form the basis of Tiers I, II, and III involve changes in processes used to produce bleached pulp. The impacts of the incentives tiers air emissions from bleaching and pulping processes are expected to be similar to BAT Option B as described in the Section 11 of the STDD.

` Mills will be burning material in the recovery boiler previously discharged with the effluent because of the substantial improvements in overall mill closure. This will tend to increase emissions of many substances to the atmosphere by up to one to two percent, as discussed in Section 7.4.2.

` The location of points of emissions of carbon dioxide (a greenhouse gas) from mill sites will change, as discussed below, but the total emission will not.

` The changes in overall energy consumption discussed in Section 7.3 will change atmospheric emissions from on-site and off-site energy production facilities (net decrease for all three incentives tiers).

` An increase in emissions of carbon monoxide will occur due to increased chlorine dioxide substitution.

7.4.1 Emissions Due to Mill Process Changes

The control technologies that form the basis of the incentives tiers involve changes in the processes used to produce bleached kraft pulp. These changes affect the rate at which air pollutants, including HAPs, are emitted from pulping and bleaching processes. The technology basis of Tier I is the same as BAT Option B, so the impact on air emissions due to process changes for Tier I will be as shown in Section 11 of the STDD. The impact of Tiers II and III are expected to be similar to Tier I, with a potential decrease in chlorinated HAP emissions due to decreased chlorine dioxide use. EPA does not have data available to confirm these projections.

7.4.2 Emissions Due to Burning Increased Quantities of Black Liquor Solids

The technology bases of all three tiers will result in recovery and burning of increased quantities of black liquor solids. As discussed in Section 11 of the STDD, this could result in a maximum 1 to 2 percent increase in air emissions from recovery boilers for Tier I. Tiers II and III result in additional recovery of organics and black liquor solids beyond Tier I. However, the resulting additional impact on air emissions due to changes in recovery boiler load is negligible compared to Tier I, as the bulk of the improvement in recovery of black liquor occurs through oxygen delignification and improved BMPs, which are reflected in the Tier I estimates. As discussed below, these air emission increases are partially offset by air emission reductions from lower net energy demand.

7.4.3 Emissions Due to Changes in Energy Consumption

As discussed in Section 7.3 and summarized in Table 7-1, each of the incentives tiers will have an effect on total energy consumption. For the analysis presented in this report, EPA estimated changes in on-site steam demand, on-site electric power consumption, and off-site electric power consumption. On-site steam demand is met by power boilers that burn wood, coal, or oil. Electrical demand is typically met by off-site electric power generating stations that burn coal or oil. For the purpose of this analysis, EPA calculated an oil equivalent to combine the effects of all energy changes (see Section 7.3.3).

As discussed in Section 7.4.2, incentives tiers all result in a net increase in combustion of black liquor solids and corresponding increased steam production. This results in decreased steam demand from on-site power boilers and lower emissions from those sources. This slightly offsets the increased emissions from recovery boilers, discussed in Section 7.4.2.

As discussed in Section 11 of the STDD, installed on an industry-wide basis, BAT Option B/Tier I would result in a 2 percent decrease in energy consumption, with resultant decreases in air emissions of 1,405,000 tons/year carbon dioxide, 6,300 tons/year sulfur dioxide, and 16.3 tons/year total particulate HAP. Tier II and Tier III technology results in further energy savings, discussed in Section 7.3, and commensurate reductions in air emissions.

7.4.4 Greenhouse Gases

EPA concluded that the technology basis of BAT Option B/Tier I will not have a net impact on the emissions of greenhouse gases from mills due to pulp processing, based on consideration of the overall mill carbon balance and energy balance. See Section 11 of the STDD for a detailed discussion of this analysis. However, changes in energy consumption will have the effect of reducing carbon dioxide emissions for Tier I. As energy consumption is further reduced through use of Tier II and Tier III technology, carbon dioxide emissions would be commensurately reduced.

7.4.5 Carbon Monoxide Emissions

EPA evaluated carbon monoxide emissions from oxygen delignification and concluded that, because MACT I requires that vents from oxygen delignification systems be incinerated, there would be efficient oxidation of carbon monoxide from this source. See Section 11 of the STDD for further discussion.

EPA estimated that baseline BAT will result in carbon monoxide emissions from chlorine dioxide use of 1,500 tons/year. Chlorine dioxide use will go down under the incentives tiers (and will be eliminated in the case of TCF bleaching), so carbon monoxide emissions will be lower under the incentives program than at baseline BAT.

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